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# A serious game about Covid-19: design and evaluation study

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**ABSTRACT**

As many countries experience the emergence of new waves of Covid-19, many governments around the world have reminded their citizens of the need for an engaging intervention that could improve compliance with Covid-19 safe behaviors using the media general public or social media. In the face of the serious threat of Covid-19, immunity issues are currently the subject of various research and studies. A promising approach is to use video game culture to educate and train citizens to healthily adopt eating habits to strengthen the immune system. The objective of this study is to develop a prototype of a serious game (SG) on how to strengthen the immune defenses in order to be able to fight a coronavirus infection and to constitute an anti-virus barrier. After defining the learning objectives by interviewing the stakeholders, we searched the scientific literature to establish the relevant theoretical bases. The learning contents have been validated by biology teachers. The learning mechanisms were then determined based on the learning objectives. The obtained experimental results show that 92% of the participants in the study have appreciated the quality of the scenario and the way in which the concept of interaction between the different game elements was presented.



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## 1. INTRODUCTION

Covid-19 is a highly contagious respiratory disease first detected in Wuhan, China on November 17th, 2019. It was the first pandemic of its kind on a global scale that has swept all regions of the world without exception and has caused devastating human suffering. The Covid-19 epidemic has evolved in waves. Between March 2020 and summer 2022, several waves were recorded, characterized by an influx of patients in hospitals and intensive care units. Now, we have to cope with Covid-19 and learn to understand Covid-19 as we understand the flu.

It is known that age and disease weaken the immune system and make people more susceptible to infections. Indeed, epidemiological studies have shown that diet, smoking, sleep, physical activity, stress, the quality of relationships, and the living environment influence the quality of the immune response [1], [2]. Therefore, we need to understand how the immune system works to protect and strengthen it.

Over the years, numerous nutritional research studies have shown that diet plays an important role in the prevention and treatment of infectious diseases. Above all, it reduces the risk of death. Indeed, according to Basu *et al.* [3], poor nutrition quality is the leading cause of death and disability in the world. Again, good communication strategies avoid confusion and mistrust that can negatively impact individuals and society

[4]. Digital health solutions could be a promising approach to the grave threat of Covid-19 [5]. Digital tools can effectively support institutions and facilitate the large-scale dissemination of information [6].

Serious games (SG) have motivational properties that can improve player engagement and satisfaction while conveying important messages [7], [8]. According to Alvarez [9], the SG is a game that combines a serious intention of an educational, informative, communicative, promotional, ideological, or training nature with ludic aspects. The use of SG is exponentially growing and extends to different areas such as health, education, economy, politics, ecology, and military [10], [11].

This article is devoted to raise people's awareness through the use of the ludic aspect of a SG, on the relationships between the general functioning of the immune system, nutrition, and the spread of the virus within the human body. Our goal is to motivate people to adopt good eating habits in order to support the immune system in order to protect it and better defend itself. This game allows players to travel through the human body and discover solutions that help strengthen immune defenses.

After this introduction, section 2 describes the related works, where some video games that are related to the theme of Covid-19 are presented. Section 3 presents the used elements to design and implement the solution. Section 4 is devoted to the protocol followed to evaluate the proposed game and we discuss in detail the results obtained from the evaluation. Section 5 contains the conclusions of the research results.

## 2. RELATED WORKS

Now, global studies are investigating solutions to stop the rapid spread of Covid-19 around the world. The response from the video game industry has been encouraging. To better understand how the Covid-19 virus works, the University of Washington team added a Covid-19 extension in the SG Foldit (released in 2008, to analyze amino acids) to design a new protein that will bind to the spike protein of the coronavirus in order to block the bindings and end the infection in the body. In order to help players, understand how the coronavirus is spreading. In the unprecedented context linked to a global pandemic, the SG Plague Inc which has been showing players how to spread a pandemic and destroy the world's population by creating an ultra-resistant virus, announced a new game mode, the objective of which is to find out how to stop the Covid-19 virus and save the population. As schools reopen in 2020, the Ministry of Education, Youth and Culture of the Canton of Vaud (Switzerland), led by cantonal parliamentarian Sesla Amarel, announced a SG CoronaQuest to promote respect for barrier gestures. More specifically, the CoronaQuest game is aimed primarily at young people for a safe return to class; this free online card game is available in 10 languages (French, English, German, Italian, Portuguese, Spanish, Albanian, Croatian, Serbian, and Bosnian) and available for download whether smartphone, tablet or computer. In addition, Gaspar *et al.* [12] developed a SG aimed at providing scientific information on Covid-19 prevention and self-care during the pandemic while assessing players' knowledge of Covid-19 related topics. Furthermore, Suppan *et al.* [13] have developed a SG that would promote infection prevention and control practices with a particular focus on Covid-19 in and around the hospital. Moreover, to enhance nursing students' understanding of the novel Covid-19, Hu *et al.* [14] designed and developed a SG that requires nursing students to solve problems using simulated cases. This game is effective for Covid-19 education especially in terms of its ability to improve knowledge retention.

While most of the studies have focused on raising awareness and improving the knowledge of students and health workers. Few studies have supported needed dietary strategies to support immunity. In this context, this article describes a prototype of a SG on how to strengthen immune defenses to fight against coronavirus infection and build an anti-virus barrier. This game aims at providing information on the link between nutrition, immunity and the spread of the virus within the human body, thus illustrating risky behaviors in order to raise awareness of the changes to be adopted to improve the immune system.

## 3. RESEARCH METHOD

The purpose of this section, on the one hand, is to discover the idea of the game. On the other hand, to present the theoretical foundations and the design details of the game. The objective is to explain the scenario followed to facilitate the design and development of the proposed SG. Essentially, the design begins with the analysis stage and then moves on to the design and development stage.

### 3.1. Serious games to raise awareness

Thanks to an experimental study intended for 80 students from two different higher education open-access public institutions (Polydisciplinary Faculty of Taza and Polydisciplinary Faculty of Nador), we sought to collect the expression of both positive and negative perceptions with regard to SGs. The experimental study was carried out in two steps. The first step is devoted to present the operation and use of

three types of learning resources selected for this study in related to the theme of Covid-19 (Table 1). The second step includes a questionnaire composed of closed questions whose answers were given according to a Likert scale from 1 (totally disagree) to 5 (totally agree) to determine the answers of the experiments concerning the utility, usability and acceptability of these three types of learning resources (Table 2).

Table 1. Learning resources of the experimental study

| Learning resources type | Thematic |
|---|---|
| Cartoon "Not the corona-virus!" | Realized by Florian Proust for Sip on March 27, 2020 to understand the Covid-19 virus. |
| Video realized by the actors of the movie "Contagion" | The entire cast of the film "Contagion" came together in a video broadcast on Friday March 27 to raise awareness of barrier gestures to fight against the Covid-19 virus. |
| SG "CoronaQuest" | Created by the Ministry of Education, Youth and Culture of the Canton of Vaud on May 11, 2020 to learn to respect the barrier gestures of young people in order to limit the spread of epidemics. |

Table 2. Indicators of utility, usability, and acceptability

| Criteria | Utility | | Usability | | Acceptability | |
|---|---|---|---|---|---|---|
| Indicators | $A_1$ | Relevance of the content proposed | $B_1$ | Adapted ergonomics | $C_1$ | Impact of types of resources on the decision-making mechanism. |
| | $A_2$ | Degree of respect for students' time and pace of learning | $B_2$ | Degree of understanding of the procedure | $C_2$ | Impact of resource types on student learning goals. |
| | $A_3$ | Relevance of the tasks proposed | $B_3$ | Simplicity and readability of content | $C_3$ | Impact of resource types on student learning time. |
| | $A_4$ | Degree of attention and motivation of students to follow the proposed activities | $B_4$ | Easy to understand and learn | $C_4$ | Impact of resource types on student culture. |

Have access to the questions online, the link is sent to them by email. The participation rate and the response rate to the questionnaire issued was 100%. According to the results of this experimental study (Figure 1), the students were generally satisfied with SGs and the majority agreed on the need for such a recognition tool. The majority of students also said that the ergonomics of the game allow both a real development of analytical skills and an improvement in memory. Overall, most survey participants agreed that SGs increase awareness. This demonstrates a positive interest in using SGs to raise awareness to curb the spread of the epidemic.

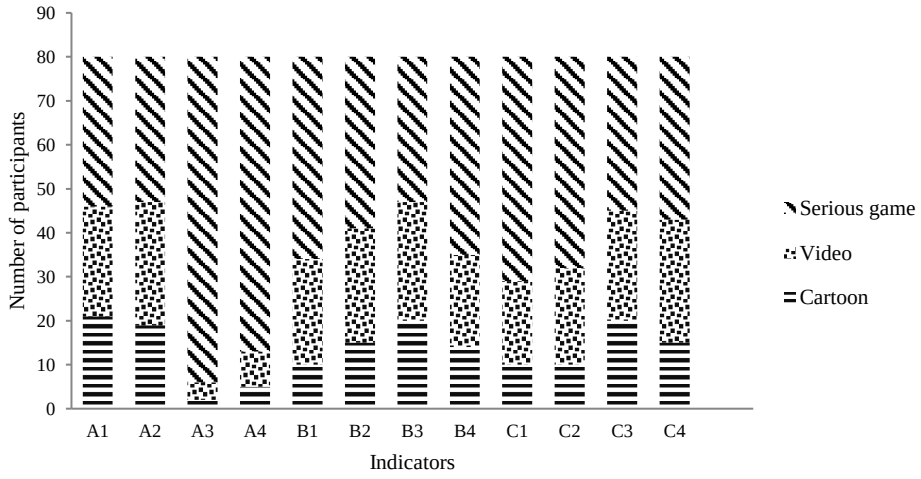


Figure 1. Results of the experimental study

### 3.2. Proposed serious game

The idea of the game is simple, having a fairly realistic scenario, representing the human body in the form of a castle, with a large tower and a drawbridge that opens to let the allies pass and closes to create a barrier for the enemy. In this castle, there are the king, families, servants, and soldiers. The player's objective is to defeat the enemy coronavirus before it spreads through the castle and attacks all families in the castle.

The proposed game is an interface to discover, raise awareness and train players to adopt good eating habits to strengthen their immune system. The universe of video games uses the human body as its main environment. The human organs represent the inhabitants of the castle. This castle constitutes stations that show the players the right eating habits to strengthen the soldiers in the fight against the enemy. The story of the proposed game (Figure 2) is divided into five main periods: happiness at the castle, the arrival of enemies, the attack of families, the arrival of reinforcements, and the stopping of enemies. Also, this game is an attack-based fighting game and in each station existed defensive weapons to strengthen the soldiers during the war against the enemy.

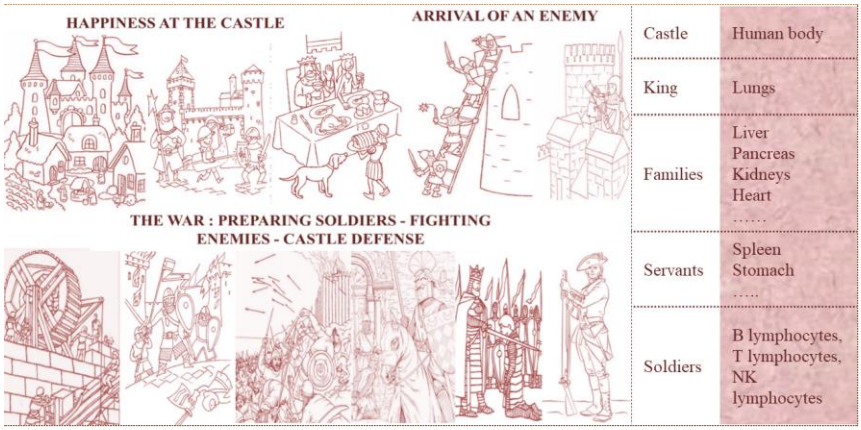


Figure 2. Story of the game

### 3.3. Game scenario

The proposed game is named the magic soldier of the human body linked to the relationship of the idea of the game with the scenario of the body's immune defense against infectious attacks. We worked on four main objectives in writing the game's scenario: a realistic universe, simple game rules, a realistic visual appearance and in-game support. The player being an avatar who can easily navigate the game world, and to start the game, the player must fill out an information sheet corresponding to their age, level of education, mother tongue, and gender; in order to profile players and store this information in an external database for later retrieval. Once these options are set, the player will be redirected to the main menu where there are some other useful settings such as the play menu to start the game and the options menu to adjust the game settings (Figure 3).


Figure 3. Main page interface

In the initial level (Figure 4), players must discover the basic nutritional needs, how to eat well and the benefits of a good diet. The goal is happiness shared at the castle by the distribution of compatible food for each family. In this level, the player must observe and memorize a list of foods needed by each family. Next, the player must set up the correct foods for each organ. If the food is successfully placed for the corresponding family, the coronavirus will have an emotion of sadness, and the soldier will improve his

strength. For each food, we have proposed coronavirus emotions and also soldier profiles. At the end of the initial level, the player learns the soldier's strength level and the general sentiment of the coronavirus.


Figure 4. Initial level interface

### 3.4. Game design and development

Players should enjoy the game, perform simple actions, and learn from the results. To achieve a satisfactory user interface, the design process was very long. However, experts have repeatedly changed their minds about which messages to send and which foods to choose. First, a paper prototype containing game requirements, learning objectives, messages to be sent to players and assumptions was discussed in detail with experts. According to Woo [15] and Prensky [16], some of the main characteristics of games that influence student engagement and enjoyment include: fun, motivation, rules, goals, challenges, competition, control, curiosity, imagination, interaction, adaptability, feedback, and multimodal presentation. Our goal was to gather early design feedback through personal interactions, rather than designing haphazard user interfaces. Also, we considered three requirements while designing our game (Figure 5). The game was designed through a rational engineering approach [17], which has based on the definition of the six core principles used in the game (Figure 6).

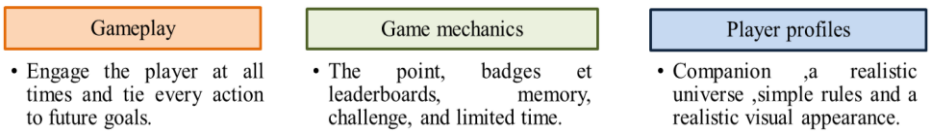


Figure 5. Design requirements of the game

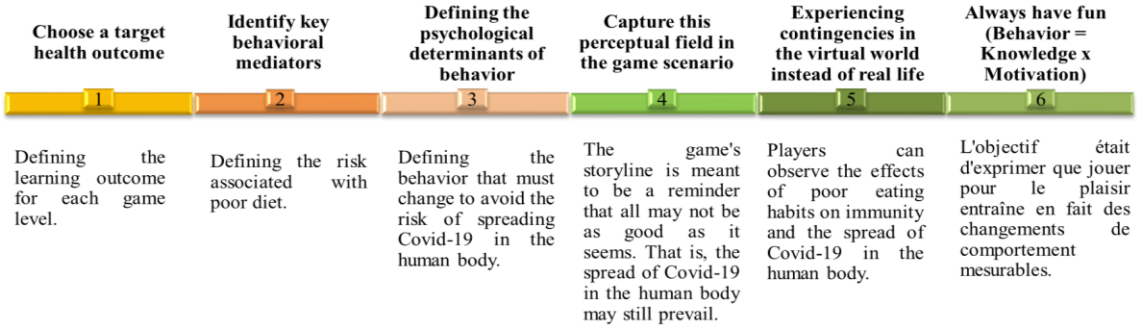


Figure 6. Six principles used in the game

In order to facilitate the design of our game we used a tool the six facets for analysis and design of SGs [18]. One of the advantages of this tool is to specify the type of most qualified experts for each aspect of the design. This method facilitates analysis in a structured and categorized manner.

The game was created in the Unity engine environment. The choice of Unity en-gine environment serves two purposes. Among other things, it offers high-quality 3D graphics tools that can be used to design virtual worlds. Second, the Unity engine is accessible to anyone on the web that allows us to collect a large amount of test data for player evaluation and tracking.

### 3.5. Learning objectives

Our game aims to raise awareness about the general functioning of the immune system in the event of a viral infection and recommended dietary strategies to support the immune system. The immune system plays a role in protecting the body against viruses and helps the human body stay healthy. The learning content of the game is grouped into three themes representing the lines of defense of the immune system (Figure 7), emphasizing the energies associated with protecting and strengthening each line of defense [19].

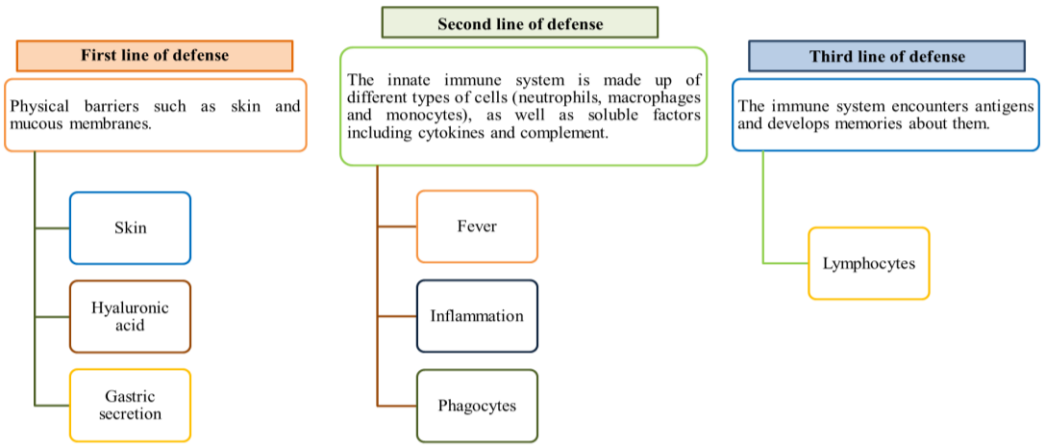


Figure 7. Learning content of the game

### 3.6. Game architecture

Effective and acceptable use of a serious game requires a strong adaptation between the ludic aspect and the serious aspect of the scenario of the game. Indeed, a coherent structure between the elements of the game is necessary to achieve the optimal balance between quality fun and educational effectiveness. To adapt this game for learning, the design prioritizes technical and interface aspects to increase motivation. Figure 8 shows the general architecture of the proposed game.

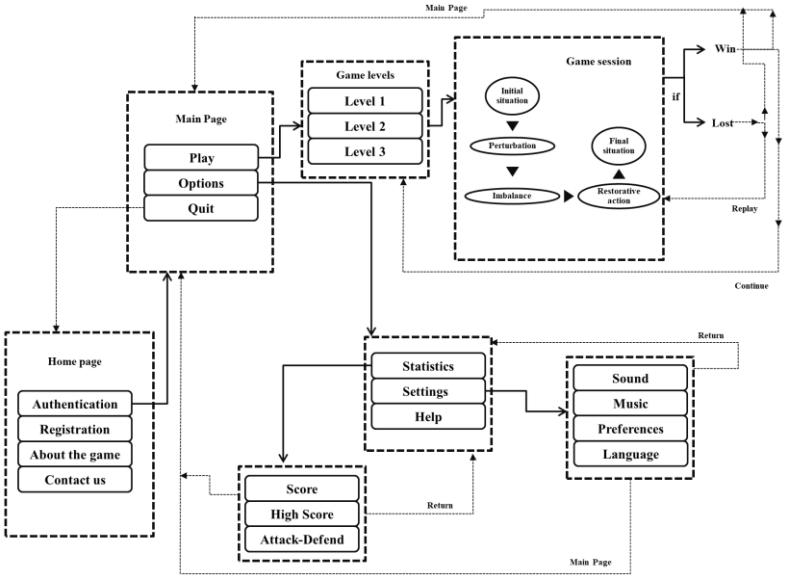


Figure 8. General architecture of the proposed game

### 3.7. Game evaluation

This part consists of explaining the followed experimental protocol to evaluate the quality and effectiveness of the SG proposed. We performed two experiments. The first experiment seeks to present the analytical and empirical study of utility, usability, and acceptability. The second experiment aims to study the effects of SGs on student motivation and behavior.

#### 3.7.1. First experiment

Senach [20] proposed a process of evaluation of a computer system based on two main dimensions: the utility, which makes it possible to check the adequacy of the contents with the objectives of the user, and the usability, allows to check the quality and the capacity of the system to allow the user to easily achieve his objectives. In addition, Tricot *et al*. [21] consider the third dimension, its acceptability. It is defined as the value of a mental representation that contains more or less positive attitudes and opinions about its utility and ease of use. According to Sanchez [22], the acceptability in the case of a SG depends on the judgment of the student, the teacher, and the institution concerned on its value. To measure the effectiveness of our game, we performed an analytical and empirical evaluation of utility, usability, and acceptability.

a. Assessment of utility

Analytical assessment of utility allows us to validate criteria that elicit cognitive responses and enhance intended learning during the design process. Empirical evaluation, on the other hand, verifies whether these criteria are relevant to achieving the learning expected objectives during the experimental phase. Table 3 lists the analytical and empirical evaluation criteria.

Table 3. Criteria for analytical and empirical assessment of utility

| Criteria | Analytical evaluation | Empirical evaluation |
|---|---|---|
| Content ($A_1$) | Check the consistency between the objectives and the content of the game. | Measures the level of relevance of game content. |
| Levels of difficulty ($A_2$) | Check the correspondence between difficulty levels and learning progress. | Measures the impact of difficulty levels on learning progress. |
| Failures and errors ($A_3$) | Check if failures and mistakes are rarely penalized | Measures the level of impact of failures and errors on learning progress. |
| Gameplay ($A_4$) | Check if the rules of the game, the narration, the game and the way in which the player appropriates the possibilities of the game are well articulated. | Measures the impact of gameplay on player decisions and learning progress. |

b. Assessment of usability

For analytical usability assessment should be performed during the design phase to check whether the criteria related to ease of use and learner enjoyment are integrated into the SG. The empirical evaluation, on the other hand, verifies the adaptation of the ergonomic and playful aspects to the characteristics of the learners during the experimental phase. Table 4 lists the criteria used for this purpose.

Table 4. Criteria for analytical and empirical assessment of usability

| Criteria | Analytical evaluation | Empirical evaluation |
|---|---|---|
| Ease of learning ($B_1$) | Check if the game tasks are simple and can be completed quickly. | Measures the degree of player satisfaction with the content to be learned. |
| Ease of use ($B_2$) | Check if game features can help players under-stand the purpose of the game. | Measures the degree of understanding of the modus operandi of the game. |

c. Assessment of acceptability

Analytical acceptability assessment verifies that learner characteristics that are taken into account in the design and availability of technological resources. Empirical evaluation, on the other hand, should check how the game can enhance player interest and motivation. The used criteria for this purpose are presented in Table 5.

Table 5. Criteria for analytical and empirical assessment of acceptability

| Criteria | Analytical evaluation | Empirical evaluation |
|---|---|---|
| Player profile ($C_1$) | Check if the characteristics of the players are taken into account during the design. | Measures the degree of compatibility of game activities with player characteristics. |
| Player ethics ($C_2$) | Check if the game is compatible with ethics and player values. | Measures the degree of compatibility of game activities with player expectations and style. |
| Satisfaction ($C_3$) | Check if the game uses different game elements (scores, badges, time limits, bonuses, leaderboards). | Measures a player's level of enjoyment while playing. |

To discover the behavior of players facing the SG proposed as an awareness support, we have made it available free of charge on social networks. A sample of 40 players got access to download the game, including 29 men and 11 women and they were in the age group between 18 and 35 years old. The players played the game and then had to give their level of agreement with data using a 5-point Likert scale ranging from "completely disagree" to "completely agree". Standard deviations were calculated for each quality criterion.

#### 3.7.2. Second experiment

Students today are heavily influenced by the digital age and constantly work with digital information and like experiential learning [23], [24]. For this reason, the second experiment aims at evaluating the use of our game as a learning medium. For this, we organized an experiment with the students of the master's degree in biology and plant biotechnology from the Polydisciplinary Faculty of Nador. A sample of 24 students who agreed to participate in such an experiment. In order to support teachers in the use of SGs in their classes, we have used the analysis method of structure, interface, and use [25], and the report of the serious game analysis (SGA) tool [26]. Then, we prepared and coached play sessions with the teachers. The session consists of a game phase followed by a debriefing phase. The objective was to help teachers to use SGs in the educational context and to observe the effects of the proposed game on the motivation and behavior of students.

## 4. RESULTS AND DISCUSSION

### 4.1. Results

The analytical evaluations carried out during the design phase have an average score higher than 3. This reflects the average level of quality of the game. For the results of the empirical evaluation carried out during the experimental phase, the average of the answers ranged from 3.35 to 4.55 and the standard deviation of the results ranged from 0.504 to 0.954. The obtained results during the analytical and empirical evaluations are presented in Table 6.

Table 6. Results of analytical and empirical assessment of utility, usability and acceptability

| Dimension | Criteria | Analytical evaluation | | | | | Empirical evaluation | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | Average | Standard deviation |
| Utility | ($A_1$) | | | | × | | 3.8 | 0.823 |
| | ($A_2$) | | | × | | | 3.35 | 0.893 |
| | ($A_3$) | | | | × | | 4.23 | 0.62 |
| | ($A_4$) | | | | | × | 4.55 | 0.504 |
| Usability | ($B_1$) | | | | × | | 4.45 | 0.639 |
| | ($B_2$) | | | | × | | 4.2 | 0.687 |
| Acceptability | ($C_1$) | | | | × | | 4.23 | 0.768 |
| | ($C_2$) | | | | × | | 3.75 | 0.954 |
| | ($C_3$) | | | | × | | 3.63 | 0.586 |

Our objective in the second experiment is to show that the proposed SG is more suitable for use in a learning context. First, we applied the grid proposed by the SGA tool to our game by signing a score for each criterion, we obtained an overall score of 18, which means that the game reached 78.3% of criteria, a percentage reflecting the average quality level of the game. Regarding the evaluation and analysis of each aspect, we obtained the presented results in Table 7.

Table 7. Results of proposed game analysis using SGA

| Phases | Structure | | Interface | | Use | |
|---|---|---|---|---|---|---|
| Aspects | Pedagogic | Ludic | Utility | Usability | Understanding | Acquisition |
| Sum of grades (%) | 85 | 80 | 74 | 92 | 70 | 65 |

### 4.2. Discussion

All items on the questionnaire are above average (mean value 3). Overall, the results of the questionnaire show that the SG presented was perceived as useful, usable, and acceptable. The results of the game analysis using SGA indicate that this SG is better suited for use in a learning context. Another, we evaluated the effectiveness of SG in teaching by analyzing the influence of the latter on student motivation

and teacher appreciation. Among the 24 students participating in the survey, 95% of the students had no unfavorable opinion on the value of using a SG in a learning session and 92.3% of them found that the use of games facilitates some learning. Also, 92% of the students appreciated the quality of the images and the way in which the concept of interaction between the different game elements was presented. Also, 80% of the participants appreciated the informed option on each mission of the game, where the player is informed about the mission before the launch in the game and advice on strategies to fight against an infection of a specific organ. However, 30% of the students were unable to complete the game successfully because the error messages in the game do not provide explanations and solutions for the errors made by the students. The teachers expressed their agreement on the need for games during a learning situation and also the need for a prior evaluation of the game content.

## 5. CONCLUSION

This article introduced the magic soldier of the human body; a SG that educates players about nutrition, immunity, and Covid-19. The game allows the player to travel through the human body and find solutions that will help him boost his immunity. The goal of this game is to motivate people to adopt good eating habits in order to support the immune system in order to protect it and better defend itself.

Overall, the protocol followed to evaluate the proposed game as an awareness tool yielded positive results with respect to usefulness, usability, and acceptability. Also, the participants of the experiment appreciated the quality of the gameplay, the visual effects and the sound effects of the proposed game. This indicates that this SG is better suited for use in a learning context as well. Finally, we hope this game will continue to fight misinformation about Covid-19, immunity and nutrition, and increase public engagement in disease prevention efforts. One of our future goals is to validate the different play contexts with other populations.

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