A Video Game to Help the Fight Against the Vicious Tapeworm in Africa

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Abstract: The pork tapeworm, *Taenia solium,* is the agent causing the most important parasitic infection worldwide due to its substantial economic and health impacts, disproportionally affecting low-income countries. Health education should form a core component in control efforts and sustain control strategies proposed by the World Health Organization (WHO), such as human treatments. Traditional health education methods have shown to be less effective. Therefore, in the field of tropical medicine, new, engaging ways to teach affected populations are needed. Within the project 'Gaming 4 Health' we developed an educational video game aimed at instructing school-going children in low-income countries about the tapeworm and how to prevent it. Building on the principles of gamified learning and the self-determination theory, we created the educational video game the 'Tapeworm Game'. The game was developed by a multidisciplinary team, following the game design research cycle which included five steps: game planning, game design, prototyping, play testing and evaluation. The 'Tapeworm Game' is a multi-player video game set in an African village. The game's objective is to educate players about the tapeworm and how to prevent the the spread of disease. Players create their own avatar and learn about disease prevention by exploring the village, engaging in minigames and preforming complementary actions, such as handwashing and visiting the toilet. Points are earned by playing the minigames and performing the actions correctly within a given time. The more points a player accumulates, the higher they climb on the leader boards. Rewards are unlocked based on performance and competence and displayed as stars, badges, and avatar customizations. This makes the game exiting and keeps children fully immersed, motivating them to learn, improve and continue playing the video game. With this video game our goal is to educate, raise awareness and advance the control of the pork tapeworm as part of the WHO's 2030 goals for Neglected Tropical Diseases.

Keywords: Serious video games, disease prevention, health education, school-going children, Africa

1. Introduction

Tapeworm infection is treatable but persists in areas with inadequate sanitation and hygiene, lack of meat inspection, free roaming pigs, and where little or no knowledge about the parasite and its consequences is present. Tapeworm infections are particularly recurrent problems in resource-poor areas of Latin America, South and South-East Asia and sub-Saharan Africa. When tapeworm larvae develop in the central nervous system, neurocysticercosis (NCC), the neurological form of the disease, occurs (Del Brutto, 2012). According to the World Health Organisation (WHO) (2021), NCC contributes to 30% of epilepsy cases in areas where the parasite is widespread (Ndimubanzi et al., 2010).

Efforts to control and eliminate the parasite have been made (Gabriël et al., 2020), but long-term interruption of tapeworm transmission has not been achieved yet. One effective way to mitigate the risks and prevent the parasite, is through health education. Health education interventions have been tested in some countries, including Zambia, Tanzania, Kenya, India, and Mexico. The results revealed that knowledge about the tapeworm and its lifecycle increased, leading to a decrease in the number of disease cases (Mwidunda et al., 2015).

Compared to traditional forms of education, game-based learning offers more engaging learning experiences and helps learners take more responsible for their own learning (Abdulmajed et al., 2015).

Research by Hobbs et al. (2018) has shown that the computer-based health education program "The Vicious Worm" which they developed, increased the knowledge of primary school students in Zambia. They also recommended focusing on school going children as they can be health agents and pass the educational messages to their communities.

However, research has also shown, that there is a need for more innovative ways to educate the population about health issues. This should be done in a way that will keep the learners actively engaged rather than allowing them to passively observe (Fogarty, 2019). In this regard, serious games can be powerful tools to

disseminate health messages and educate affected populations. In particular, video games provide extensive player involvement and immersion, and can support health message delivery in an entertaining and engaging format (Perttula et al., 2017).

Within the project 'Gaming 4 Health' we developed an educational video game with the aim of educating school going children in low-income countries about the tapeworm and how to prevent it.

2. Objective

The objective of this study was to develop and test a serious video game for disease prevention in an African context, using the tapeworm as a disease example.

3. Methodology and Results

Building on the theory of gamified learning and the self-determination theory, the educational video game the 'Tapeworm game' was developed. The game was created by a multidisciplinary team, following the game design research cycle by Espinosa-Curiel et al. (2020). The cycle included 5 steps, see Figure 1.

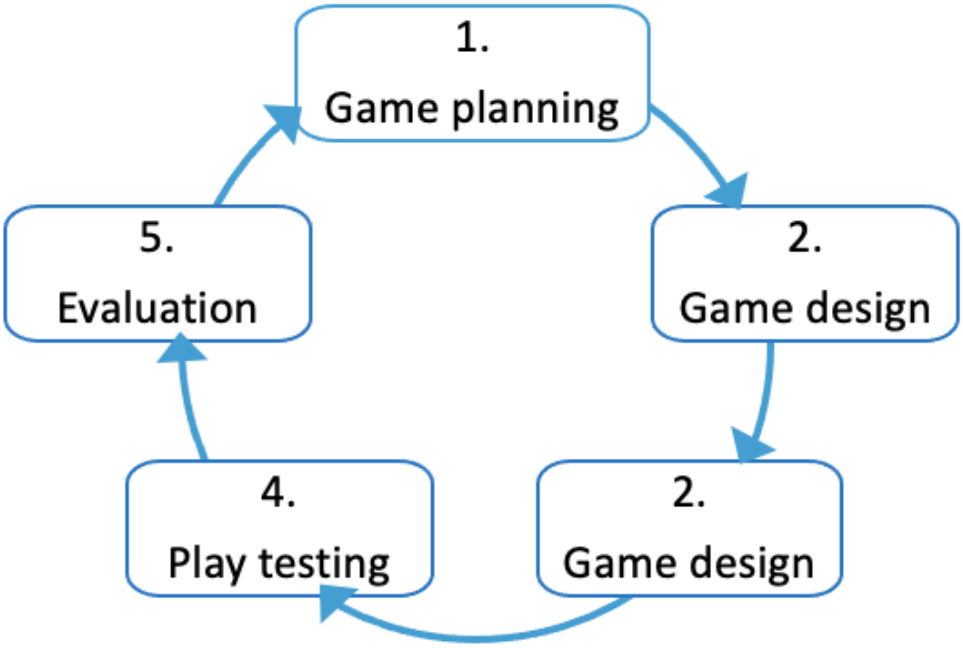

Figure 1. Serious video game design cycle

3.1 Game planning

The overall goal of the game is to educate players about the correct measures to prevent the spread of the disease. In step 1, the multidisciplinary team consisting of a game developer, parasitologists and education scientists convened several meeting to determine the elements that should be included in the serious game and to identify key health messages for disease prevention and behaviour change. Drawing on the self-determination theory of Ryan and Deci (2000), which provides a framework for the study of human motivation, three fundamental needs were considered during the game planning phase and subsequently integrated into the game design. These needs encompassed the need for competence, relatedness and autonomy (Ryan & Deci, 2000). Regarding the key health messages, the emphasis was placed on sanitation and food hygiene which included the importance of handwashing, using proper toile facilities, inspecting and cooking meat thoroughly and confining pigs to prevent infection.

3.2 Game design

In step 2, we implemented feedback loop sessions following an iterative game design approach. Game mechanics and rules were developed based on the outcome of three game planning sessions. The key messages identified earlier were transformed into in-game scenes and adapted to fit the local context.

The video game was designed in a way that players would learn five core messages for disease prevention by engaging in four minigames and performing two repetitive, but complementary behaviour change actions. The

fulfil the need for competence, we provided relevant feedback, such as using badges or stars to indicate the players achievement level (Wong et al., 2020). To create sense of relatedness, we incorporated collaborative learning, allowing players to track the progress of classmates who were also playing the game (Gopinath Bharathi et al., 2016; Wang & Huang, 2021). Lastly, drawing from the work of Bavelier and Green (2019) the game displayed the player's current performance status sand goal achievements, while offering challenges, in-game choices or decision-making opportunities to enhance player autonomy (Bavelier & Green, 2019). This autonomy was furhter supported by allowing the players to create custom avatars and compare themselves with others.

3.3 Prototyping

In step 3, we developed the video game prototype using the Unity video game engine. The "Tapeworm Game" is a multi-player video game set in an African village (Figure 2). When players start the game, they have the opportunity to create their own avatars and learn about disease preventions by exploring the village, engaging in four minigames, and preforming complementary actions. One minigame aims to explain the importance of inspecting meat for larvae, requiring players to remove as many larvae as possible within a given time frame. In the second minigame the emphasis is on cooking. Players must light a fire and cook the meat at the right temperature to prevent human infection. The third minigame uderscores the importance of confining pigs by challenging the players to build a pigsty (Figure 3). Complementary actions in the game include washing hands and visiting the toilet to teach the importance of hygiene and sanitation.

Points are earned by playing the minigames and correctly performing the actions (visiting the latrine and washing hands). The more points a player accumulates, the higher the scores on their leader boards. Rewards are unlocked based on performance and competence, displayed as stars and badges. These rewards and avatar customizations make the game exiting and keep players fully immersed, motivating them to learn, improve and continue playing the video game.

Figure 2. Multi-player video game set in an African village

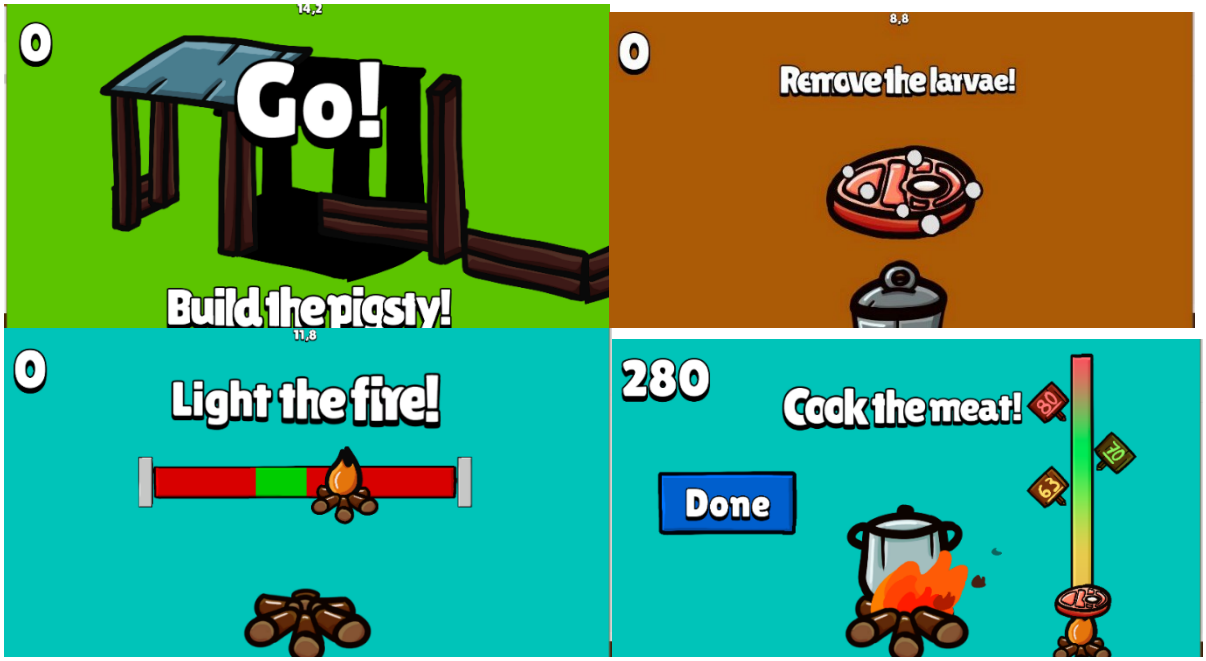

Figure 3. Four minigames: Build the pigsty, remove the larvae, light the fire and cook the meat.

3.4 Play testing

Step 4 involved testing the video game. Due to the Covid-19 pandemic, the pre-post gaming experimental study was conducted in 2022 in three schools in Belgium, instead of in Zambia, as initially planned.

3.4.1 Research questions

The study was guided by two research questions:

Q1. Did the students involved in the experimental condition using game-based learning achieve higher learning performance compared to students in a control condition based on explicit instruction?
Q2. Did the students in the experimental condition using game-based learning achieve higher intrinsic motivation compared to students in a control condition based on explicit instruction?

3.4.2 Study Design

The schools were selected based on opportunity sampling. One class per school was chosen, and atwo-hour workshop was organised, including a total of 60 pupils. Initially, a brief introduction to the workshop was given. Then, baseline knowledge was assessed by administering a pre gaming questionnaire to the entire class. The classroom was subsequently divided randomly into one control and one experimental group. The control group moved to a different classroom and received explicit instruction about the tapeworm through a traditional presentation in Dutch using a PowerPoint presentation given by one of the researchers. The experimental group remained in the same classroom with another researcher and played the video game. After one hour, all participants reconvened in one classroom and completed the post-gaming questionnaire.

To measure learning performance, the pre-post gaming questionnaire was developed as a multiple-choice questionnaire, covering the health educational messages presented in the video game. An example of such a question was “How do you cook your meat to kill the eggs of the pork tapeworm?”. Each question had one correct answer out of four choices.

3.4.3 Data collection and analysis

The data was collected using paper-based pre-gaming and post-gaming questionnaires. Next the data was transcribed in Excel using a coding manual and analysed. A maximum of fourteen points could be earned, with each question being worth one point when answered correctly.

3.4.4 Results

In total 60 children between 10 and 12 years old took part of the study, including 28 females (47%) and 32 males (53%). The control group consisted of 29 participants, including 17 males and 12 females. For the experimental condition included 31 participants, with 15 males and 16 females. Table 2 summarizes the mean and standard deviations for the research variables.

Table 2 Mean and standard deviation of research variables

Variables Learning performance	**Control (n=29)** **M(SD)**	**Experimental (n=31)** **M(SD)**
Pre-test	6.59 (1.35)	5.69 (1.90)
Post-test	8.50 (6.54)	6.65 (1.80)
Intrinsic motivation	5.69 (1.11)	7.86 (1.51)

Figures 4 and 5 display the baseline knowledge of the students in the experimental and controlled conditions. Among the 31 students in the experimental group, 6 achieved a score of ten points. The highest score obtained was 12 points. Notably the scores on the post-test exhibited a wider distribution compared to those of the pre-test. Two students scored 13 and 14 points on the post-test. Additionally, 21 students scored 7 points or higher on the pre-test, while 26 students achieved this on the post-test. In the control group it was evident that the students preformed better on the post-test than on the pre-test, with most students scoring 12 points or higher in the post-test.

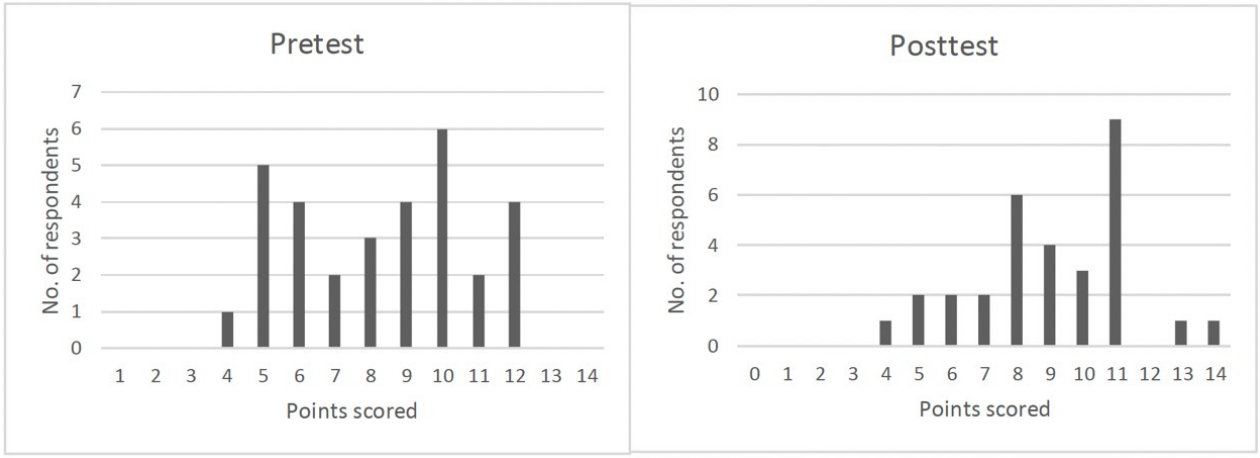

Figure 4. Distribution of pre and post test scores for the experimental group playing the video game.

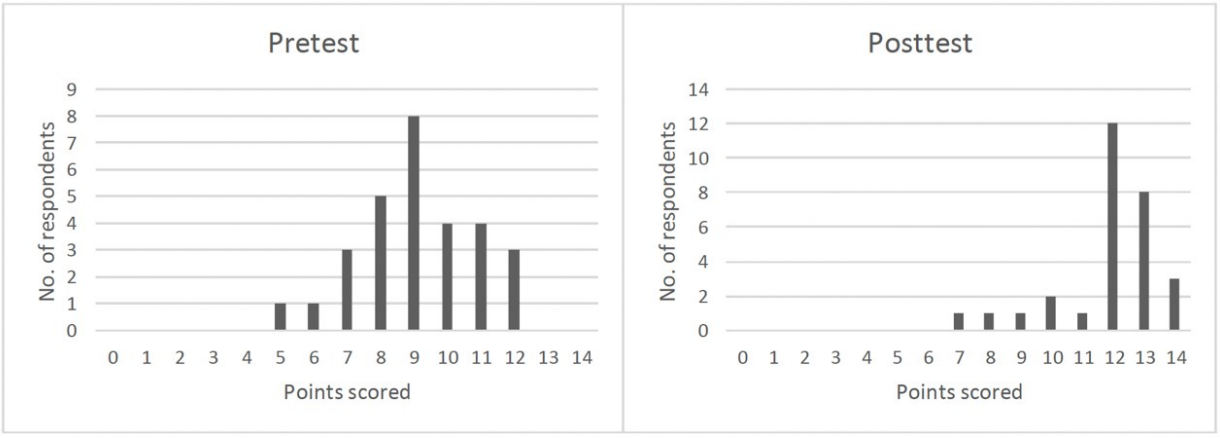

Figure 5. Distribution of pre and post test scores for the control group.

A univariate analysis was conducted to test the impact of condition on learning performance. Statistical analysis revealed that there was a significant difference between both conditions for learning performance $F(1, 58) = 18.33$, $p < 0.005$. Notably, the students in the control condition outperformed the experimental group.

In terms of intrinsic motivation, the results showed a significant interaction between intrinsic motivation and condition, $F(1, 58) = 40.08$, $p < 0.005$. Learning in a gamified condition had a positive effect on the students' intrinsic motivation.

3.5 Evaluation

Step 5 involved the game evaluation by the pupils that participated in the experimental study. Additionally, a group of educational sciences students from the Faculty of Psychology and Educational Sciences of the Ghent University, Belgium, provided additional feedback for improvement.

Subsequently, all the user feedback obtained in step 5 was collected, analysed, and discussed in an additional multidisciplinary session. Changes for improvement were recommended for a new prototype.

For evaluation, the EGameflow questionnaire, which measures enjoyment offered by eLearning was used (Fu et al., 2009). This questionnaire helped in understanding the strengths and weaknesses of the game from the learner's perspective (Fu et al., 2009). To assess user satisfaction with the video game, a questionnaire was developed based on the GUESS questionnaire (Phan et al., 2016). A description of the categories used in the two questionnaires is summarised in Table 3. To accommodate younger children who might have difficulty reading, smiley faces were added to visualise the Likert-scale from one to five in the questionnaires (Yahaya & Abdul Salam, 2008).

Table 3. Questionnaires' categories and content

Category	*Content*	*Category*	*Content*
Concentration	The game grabs my attention	**Usability/Playability**	I think it is easy to learn how to play the game
Goal clarity	I understand the learning goals through the game	**Play Engrossment**	I feel detached from the outside world while playing the game
Feedback	I receive immediate feedback on my actions I receive information on my status, such as score or level		Whenever I stopped playing the game, I cannot wait to start playing it again
Challenge	The game is too difficult The game is too easy My skill gradually improves through the course of overcoming the challenges	**Enjoyment**	I think the game is fun I am likely to recommend this game to others
Autonomy	I can make choices in the game	**Creative Freedom**	I feel my curiosity is stimulated as the result of playing the game I feel I can explore things in the game
Immersion	I forget about time passing while playing the game	**Personal Gratification**	I want to do as well as possible during the game I feel the game constantly motivates me to keep playing
Knowledge Improvement	The game increases my knowledge about prevention methods of the tapeworm I catch the basic ideas of the knowledge taught	**Audio Aesthetics**	I feel the game's audio (e.g. sound effects, music) enhances my gaming experience
		Social connectivity	I can play the game with other players if I choose I enjoy the social interaction within the game
		Visual Aesthetics	I think the game is visually appealing

3.5.1 Video game analysis and assessment from primary school pupils

In total, 31 children (15 males, 16 females) from the experimental group provided feedback on the video game after playing it.

Figure 6 illustrates the responses of the participants on the evaluation questionnaire. The questions "I receive information on my status, such as score or level" and "I understand the learning goals through the game" received the highest scores, with 17 children giving 5 points to both statements. The statement that received the lowest score was "I receive immediate feedback on my actions".

The pupils also responded to a few open-ended questions. When asked about what they liked about the video game, many pupils appreciated the ability to customise their own avatars. -Participants also expressed their enjoyment in the minigames. Furthermore, the aspect of learning through playing a video game was a common positive feedback point. In response to the question: "What did you dislike about the game", children often mentioned the frequent handwashing requirement, which they found less enjoyable and somewhat boring.

Some suggested including visuals of the tapeworm and adding sound to enhance the game.

In the third question, which inquired whether they enjoyed learning through playing, all participants answered "yes". The most common reasons cited were that playing a game is much more enjoyable than attending a traditional lecture.

Lastly, pupils provided some general remarks. One suggestion was to incorporate the possibility of unlocking other worlds or buildings within the game. It was also recommended to include more levels and minigames to prevent boredom after extended play.

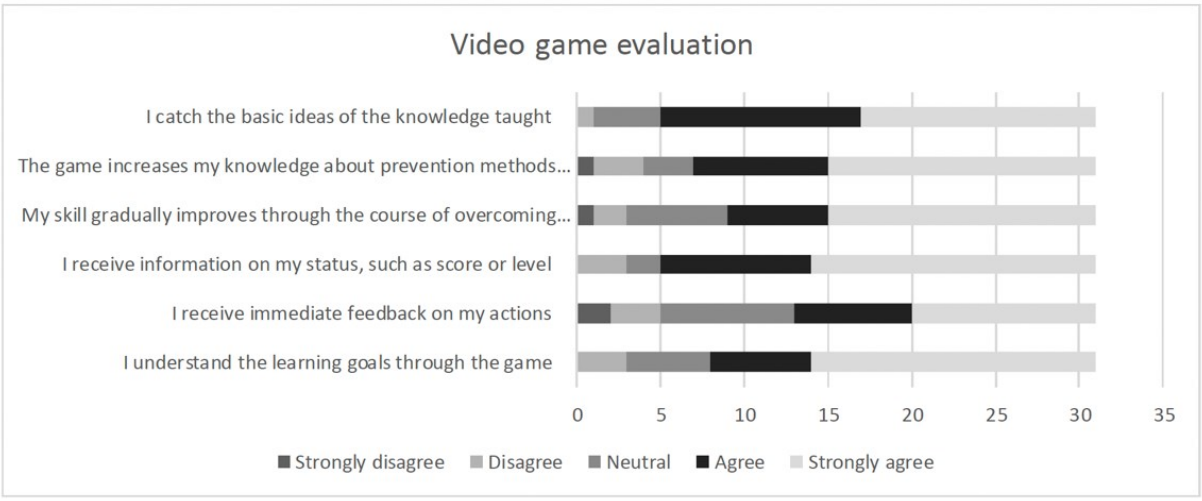

Figure 6. Pupils' responses on the video game evaluation (number of respondands on the x-axis)

3.5.2 Video game analysis and assessment from education science students

Fourteen third-year bachelor students were engaged in the video game analysis and assessment. These students were introduced to the project, asked to play the game, and requested to provide feedback by responding to the Egameflow and GUESS based questionnaires.

The responses of the third-year students are presented in Figure 7 and 8. According to the students, the visuals of the game were appealing, with eight students strongly agreeing, and five students agreeing. The students expressed a desire to perform well while playing the game. Additionally, they concurred with statements such as, "It is easy to learn how to play the game", "I have the feeling I can explore things in the game" and "The game is fun to play". The statement that received the lowest agreement was that the game is too difficult with seven students strongly disagreeing, and five students disagreeing. However, when asked if the game was too easy, sevens students responded neutrally and six students agreed (Figure 7).

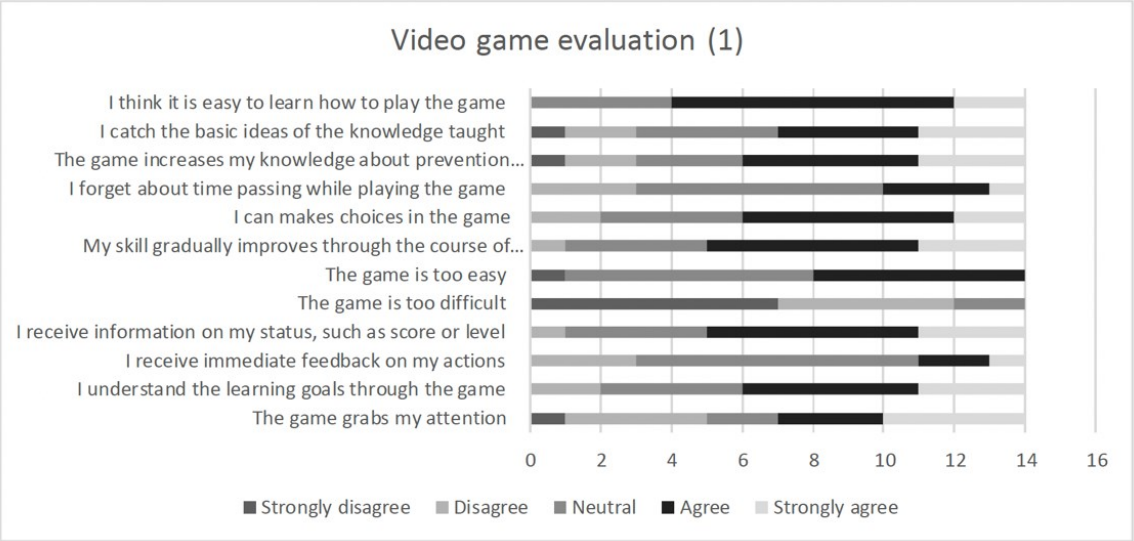

Figure 7. Bachelor students' responses on the video game evaluation (part 1) (number of respondents on the x-axis)

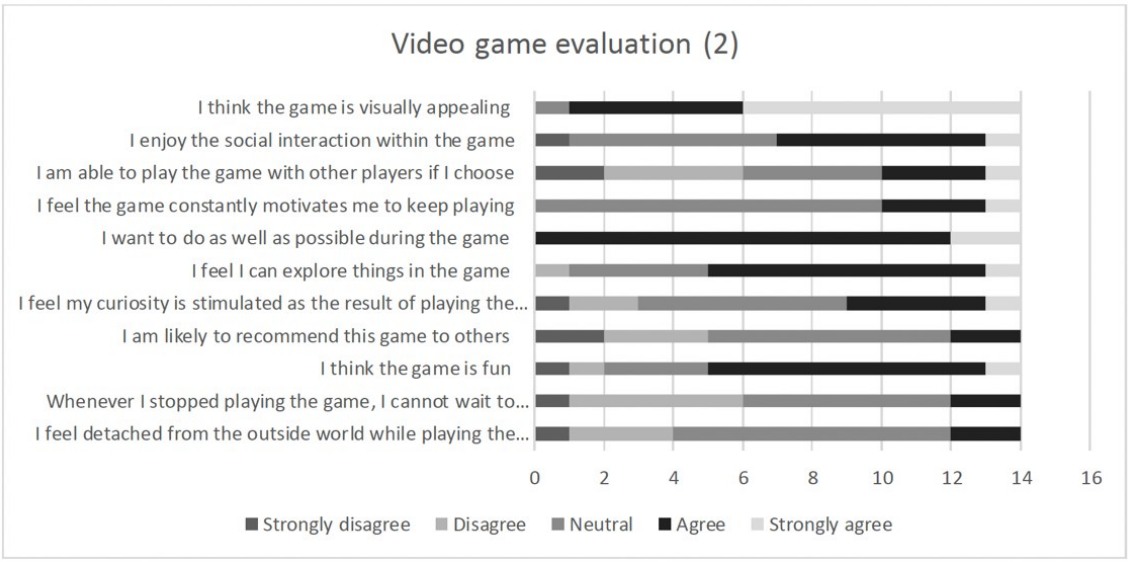

Figure 8. Bachelor students responses on the video game evaluation (part 2) (number of respondents on the x-axis)

The bachelor students also responded to several open-ended questions regarding their likes and dislikes about the video game. The most common positive feedback was related to the customization of avatars, which was seen as a significant asset. Additionally, the layout of the game received appreciation.

On the other hand, the minigames were perceived as becoming boring after a while due to limited variation, especially the activity of handwashing. Some students suggested that the handwashing action could be made more engaging.

When asked about the value of learning through playing, the students noted that the video game served as an accessible tool for children, but lacked a clear theoretical framework.

Finally, the students provided some suggestions for optimizing the game. One student proposed that children should be encouraged to think more about what they need to do to prevent the spread of the tapeworm as the game progresses. Other students recommended that the minigames and scores should be supplemented with explanatory text. For instance, the handwashing activity could include information on the recommended duration, technique, and reasons for proper handwashing.

4. Discussion

In the project 'Gaming 4 Health' an educational video game was developed to educate school going children in low-income countries about the tapeworm and how to prevent it. Due to the Covid-19 pandemic, the game was developed, tested and evaluated by Flemish school going children and third year bachelor students from the Faculty of Psychology and Educational Sciences of the Ghent University in Flanders, Belgium. The study's results revealed that participants who learned through the video game did not achieve higher learning performance scores after playing the video game, compared to the control group. This finding contrasts with the literature, which often highlights game-based technology as an effective tool for teaching children (Baranowski et al., 2016). One possible explanation is that the theoretical framework withing the current version was not clear enough Participants, both children and educational sciences students, expressed difficulties in understanding what the game was trying to teach them and its relevance to tapeworm prevention. To address this, a storyline was added to provide more background and context for the behaviour change actions required in the minigames. However, it is essential to note that the data collected on the impact of game-based learning on learning performance was not context specific. Therefore, a follow up study in Zambia is necessary to draw further conclusions.

Regarding the second research question, the analysis demonstrated that learning in a gamified condition positively affected the intrinsic motivation of the students. Students in the experimental condition exhibited higher intrinsic motivation compared to those in the control condition, which received explicit instruction. This finding aligns with previous studies that have shown serious games to enhance motivation in learning activities and promote better academic achievement among children (Froome et al., 2020; Wong et al., 2020).

The results of the video game evaluation support the idea of serious games as effective health education tools for children. Almost all children expressed a preference for learning through play, emphasising that game-based learning is much more engaging than traditional lectures. Participants provided valuable insights into the strengths and weaknesses of the game and offered suggestions for optimization. However, guidelines on developing serious games, particularly regarding how to support collaborative learning and play, remain limited.

It is important to acknowledge some limitations of the current study. The final version of the game still contained bugs and lacked sound effects, potentially affecting gameplay and user engagement. Additionally, the study recognises the need for a larger sample size to ensure results with sufficient power for generalization. Finally, there is a notable difference in the context of testing the game with children in Flanders compared to rural areas of Zambia, where exposure to video games may be less common.

In future, the optimised game will be tested with a larger sample to ensure that the gamified condition indeed enhances learning performance. Additionally the video game will undergo testing in Zambia to analyse its effects in a different context. A follow-up study could explore the long term effects of the game in Zambia to determine if the newly acquired knowledge about the tapeworm remains prominent and contributes to tapeworm control efforts.

5. Conclusion

In this study, we detailed the process of developing a serious video game for disease prevention in Africa. The results indicate that the developed serious game hold promise as a health education tool for primary children, provided that the necessary improvements are implemented. Nearly all children expressed a preference for learning through play, emphasizing that game-based learning is much more engaging than traditional lectures. However, based on the findings and evaluations, further optimization of the serious game is needed to enhance learning performance. Subsequently, a longitudinal study can be conducted in Zambia to assess the impact of the serious game on controlling -the tapeworm.

In the next phase, the game will undergo testing and evaluation in an African setting with the aim of educating, raising awareness and contributing to the control of the pork tapeworm, aligning with the WHO's 2030 goals for Neglected Tropical Diseases.

Author contributions

Study design & conceptualization: all authors; data curation & analysis: MJ, FE; writing – orginal draft: MJ, CT; writing – review and editing: All authors.

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