Initial Development of "Infection Defender": A Children's Educational Game for Pandemic Prevention Measurements

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Keywords: Health, Education, Pandemic, COVID-19, Web Application, Serious Games.

Abstract: Using serious games to communicate and teach complex topics to children and adolescence has gained a lot of popularity, especially in the medical fields. The spread of COVID-19 and the need to change everyday habits has opened up the need to teach children the required precautions for limiting the spread of potential pandemics. In this paper we present the initial development of the game *Infection Defender*, promoting children's awareness of closing schools, social distancing, testing and hospitalization for fighting the spread of infectious diseases in Denmark. These activities are given in the hands of children, between 10 and 13 years old, and the goal of the game is achieving a balanced response to a possible infectious decease outbreak. We present the game, its design considerations and how the learning objectives are integrated into it. An analysis of the game by pedagogical workers is made and a pilot test is carried out assessing children's reactions to it. Initial positive feedback shows that the game sparks interest and discussion in children and can be used as part of the study curriculum to help children understand the need for certain measurements. The game code is available online - https://github.com/IvanNik17/InfectionGame.

1 INTRODUCTION

Serious games and gamified experiences are becoming more and more widely used for teaching complex topics to both children and adults, especially in the field of health education (Lu and Kharrazi, 2018). The tendency of developing such games has shown a steady increase starting from the early to mid two thousands and their target audiences have expanded from professionals, to children and adolescents. The topics of such games have also expanded to cover a wide array of health concerns, problems and good practices. Such topics range from oral health education games (Malik et al., 2017), to mental health education games (Lau et al., 2017) and improving eating habits (Chow et al., 2020). Serious games have proven especially important, with communicating best practices and behaviours for prevention of the spread of diseases. These serious games can be build as e-learning packages (Eley et al., 2019), that can be implemented as part of the curriculum of students, as a package of educational experiences (Hale et al., 2017) or as mobile (Molnar and Kostkova, 2018) or as virtual (Clack et al., 2018) and augmented reality (Kang and Chang, 2019) experiences. Games that address directly infection and disease understanding and prevention are being researched (Castro-Sánchez et al., 2016), especially with the rise of education needs in the face of pandemics like the COVID-19 one. In this paper we present the initial development and testing of an educational infection prevention serious game "Infection Defender". The game is directed towards 10 to 12 year old children and aims to introduce the concepts of social distancing, infrastructure lockdown and the problems with hospital capacity. We go through the process of designing the game experience, as well as the initial evaluations, both from teachers, as well as from students.

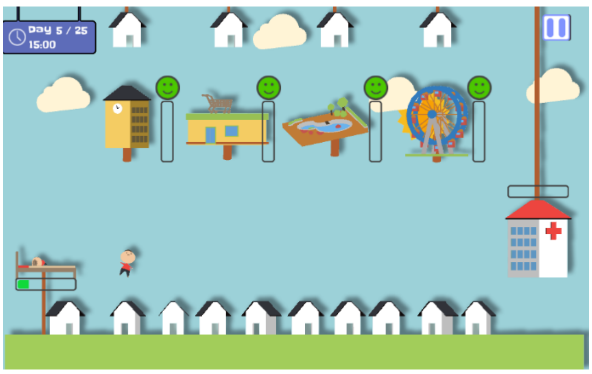


Figure 1: A view from the developed game "Infection Defender" presented in the paper.

Nikolov, I. and Madsen, C.
Initial Development of "Infection Defender": A Children's Educational Game for Pandemic Prevention Measurements.
DOI: 10.5220/0010284102530260
In *Proceedings of the 16th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (VISIGRAPP 2021) - Volume 1: GRAPP*, pages 253-260
ISBN: 978-989-758-488-6

2 STATE OF THE ART

It has been shown that serious games can improve student engagement, help with topic understanding and influence learning outcomes, when introduced as part of the learning curriculum (Huizenga et al., 2017). Even with these benefits, the introduction of serious and educational games in classes is still very limited. For health education, serious games are used as tools to help with getting a better understanding about vaccinations (Ohannessian et al., 2016), food hygiene (Young et al., 2019), antibiotic resistance in bacteria (Molnar, 2017; Govindan, 2018).

With the increased need for proper information dissemination to both adults, children and adolescences with the spread of the COVID-19 pandemic, a number of educational games have been developed. These serious games tend to tackle ideas such as social distancing, infection spread, the importance of testing and good hygiene practices. Some of these gamified experiences are directed at instructing personal on proper containment procedures (Suppan et al., 2020) and takes the form of e-learning materials containing a mix of interactive experiences, videos and tests. Other experiences use the pandemic data present online, to create simulation like environments to visualizing how infections spread on a local (Observable, 2020) and global (Tuovinen, 2020) scale. These experiences put the power of choice in the hands of players and use these choices to achieve different ending. Through these endings, users can see how following best practices can help not only themselves, but the people around them. These games adapt a more serious tone and clean design, which can be deemed not appealing to younger children. Other educational games rely more on the simplified representation of a pandemic and use more simple and easy to grasp game mechanics and visuals (Jacob and Wiseman, 2020; LuluLab, 2020), more suited for younger children. These games simplify the ideas of social distancing, treatment, wearing mask.

For developing our proposed solution we try to strike a balance, between a simplified approach to representation of the many different problems associated with dealing with pandemics and developing a game that can be used for self-reflection and evaluation of the players choices. To do this we develop a simple gameplay concept, inspired by the approach presented by (Molnar and Kostkova, 2018) and combine it with a system that takes into account the different player choices, which can be later viewed and accessed in easily to understand and clean graphical form.

3 METHODOLOGY

The game development will be discussed in this section, going from the initial idea inception, through the choice of the main topics of the game - closing infrastructures, social distancing, testing and hospitalization to limit infection spread. We will also look at how each of these topics has been introduced in the game and how the idea of achieving balance between lowering the infection rates and keeping people safe and dealing with the consequences of prolonged lockdown measurements. Finally, we will discuss the tools used for visualizing the consequences of the players' actions and how they can be used as a positive teaching feedback loop.

The application is built in the Unity game engine, utilizing a simple one screen style, which is easy to port to different platforms like mobile and tablet or web-based. The visual style relies on a 2.5D combination of polygonal objects and sprites, which is aimed at a younger audience and emphasises lightweight visuals, which should run on a wide array of hardware.

3.1 Initial Idea

The driving force for developing the game is creating a engaging, easy to understand and educational application, which can be used as a supervised tool, part of a study curriculum. Pandemic and COVID-19 spread visualization materials currently present are directed more to the general public (Observable, 2020; Tuovinen, 2020) and lack an easy to comprehend interface and engaging gameplay, that would make them appeal to younger children. On the other hand, there are the children oriented education games like (Jacob and Wiseman, 2020; LuluLab, 2020), which try to teach good habits to children, but lack a more serious look on how, the players' choices have affected the game's outcome, which is proven to be a strong learning tool (Taub et al., 2020).

The main topics we look at are social distancing, closing of infrastructures, hospitalization and the effect of the pandemic and social precautions on people's mental health. The most important topic is social distancing, as this is an idea that has become prevalent in lowering the transmission rates of infections. It can also be seen as a new concept for younger children, which changes the way they interact with one another, their family, teachers and random people in their everyday life. The second topic is the closing of infrastructures like schools, parks, shops and others, which help limit the spread of infections, but also drastically changes the day to day lives of children. The testing and hospitalization are also topics, which can prove hard to explain to younger children. Finally, the topic of the consequences of all these measurements on the mental state of everyone that experiences them.

Next a design philosophy for the developed game needs to be selected. We choose to build the game around the idea of balancing between four main factors - amount of people sick in society, the maximum possible hospital capacity, the possibility to enforce stronger or lighter social distancing measurements and the mental health strain that these can have on people. The game should have multiple levels, as this has shown to produce more engagement (Wehbe et al., 2017; Korchi et al., 2020) and each level should last for a set time limit, shown to the players as days. This would again mimic the real world problems of prolonged social distancing. A view from the main screen of "Infection Defender", can be seen in Figure 1.

3.2 Designing the Gameplay

The main factors of the game can be extremely complicated to visualize and communicated, even to adults. This is why special care needs to be taken for expressing them in a way that children can understand and relate to. It is shown that children respond better to visual cues and explanations (Javora et al., 2019), even though these visual do not help with learning, they help with directing and keeping the attention of children. The majority of the game design concerning pandemic topics is thus developed as visual concepts.

The core playability of the designed game revolves around the formula of catching and dodging. These types of fast passed gameplay are shown to have a positive influence in the possibility of children learning and understanding the information, being given through the gameplay experience. Having chosen the main gameplay loop, each of its parts needs to be connected to one of the four main factors. The three parts of the catching and dodging loop are:

- Obstacles and rewards are spawned at one part of the game field
- A player-controlled character dodges obstacles and collects rewards at the center of the game field
- A end zone collects the missed obstacles and rewards, changing a player score

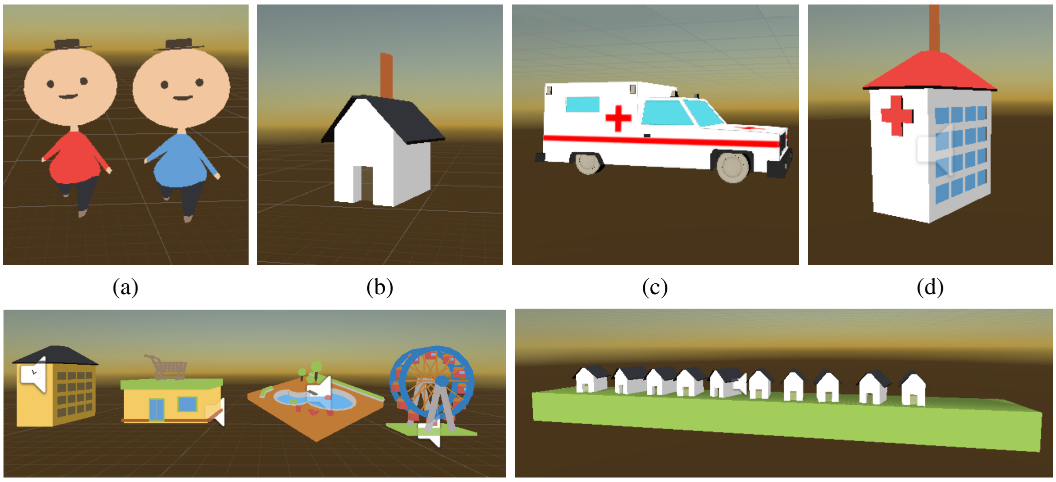
The first part of the gameplay loop, is where healthy and infected people can spawn. A cartoon 3D model of a person is created for this (Figure 2a), for easier association, where healthy people are spawned with blue shirts and infected people with red shirts. This is done for easier color differentiation. To make the visual representation of this easier to understand, these people are spawned from houses, which are shown as part of society (Figure 2b). They can then go into one of four possible infrastructures - a supermarket, a school, a park with a pool and an amusement park (Figure 2e). This represents what a person could do in a normal everyday life context, without any social distancing restrictions in play. Here the first interaction possibility is given to users - they can choose to open or close these infrastructures, effectively limiting the number of people that can spread a possible infection. Once a infrastructure is closed, another of the main factors comes into play - the gradual decrease in people's happiness. This happiness is decreased every day, while the infrastructure is closed, until it's reopening, when it starts to increase.

The second part of the gameplay loop is represented a player controlled character that can catch infected people and send them to the hospital. For the character we have chosen a representation of an ambulance, where sick people can be intercepted (Figure 2c). Here another of the chosen factors is developed - the player can try to catch every infected and send them to the hospital, but that would take up all of the hospital's capacity (Figure 2d). The third part of the loop is the end zone, where the healthy people and the infected ones, missed by the player would end up. This is represented with houses, which represent people visiting their friends, family or relatives and if infected, unknowingly spreading the infection (Figure 2f).

Four endings are possible for each level, representing problems faced by people and governments at times of epidemics spread:

- The player lets too many infected people pass and the infection spreads too much
- The player hospitalizes too many infected people, resulting a shortage of hospital beds
- The player leaves the infrastructures closed for too long, resulting in in a deterioration of people's mental health and happiness
- The player manages to navigate the epidemic for a set number of days, without any of the first three endings happening

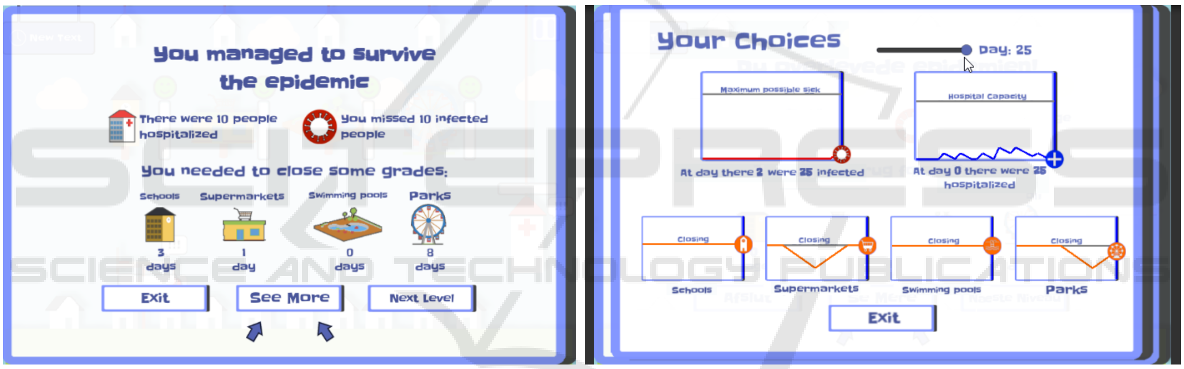
This combination of endings creates a sense of uncertainty and the possibility of experimentation with different play strategies, which have been shown to help with engagement and interest (Nugroho et al., 2018; Tancred et al., 2018). This ties to the post-level experience, where the consequences of the players actions are visualized.



(a) (b) (c) (d)

(e) (f)

Figure 2: Parts of the gameplay loop - infected and healthy people (Figure 2a), houses which spawn new people (Figure 2b), ambulance used by the player to catch infected people (Figure 2c), hospital building, where infected people go and which has maximum possible capacity (Figure 2d), different infrastructures, which can be closed to slow down the infection spread (Figure 2e) and houses representing society (Figure 2f).



(a) (b)

Figure 3: Two of the end screens of the game giving information to the player. Figure 3a is the end of level visualization, showing what were the end results from the decisions of the player. The results are separated into - how many people were hospitalized, how many people have spread the infection and how many days was each of the infrastructures closed. From this screen users can either go directly to the next level with higher challenge or go and see the more detail results Figure 3b. Details screen, shows the day by day choices and progress of the player, for how many people were hospitalized, how many left the hospital, how many were missed and how the happiness and mental health changed depending on the opening and closing of infrastructures.

3.3 Post-level Statistics

Once a level is finished, no matter the achieved ending, the post-level statistics are visualized. These are separated in two screens. The first one (Figure 3a) represents a more easily approachable overview of the consequences from the level, where everything is presented in the form of a combination of images and snippets of text. In this screen the overview of how much infected people have been hospitalized, how many have been missed and how many days have the different infrastructures been closed is given. The second screen is given as a optional experience, which is designed to be used, as part of a class discussion or together with an teacher or parent. In this screen the day by day changes in the overall infected and hospitalized people, as well as the decrease in happiness for each closed place, through the played level are given (Figure 3b). Here users can freely move through the different days and see how their choices have influenced the different parts of the game and where potential problems have started to arise.

The two post-level statistical screens are designed, with the idea to provoke discussion and a sense of curiosity. Users should be able to easily see, how their interactions and choices have invoked a certain level ending sequence. And more importantly these parts of the game are designed to provide a sense of reflection and the desire to understand and try again.

4 TESTING

The main concepts of the game and the gameplay loop are initially tested through a series of internal collaborator testing. Once the overall feel of the game and its components, menus and basic visuals are selected, the second part of the evaluation is done through a collaboration with an external primary school teacher. The teacher evaluated the application and the possibility of using it as part of a curriculum or self-study sessions on the topic of decease and infection prevention. Finally, an unstructured playtesting session is arranged with a class of 11 to 12 year old children. After the play session, kids are asked question about what they liked and disliked about the game, as well as what they learned and what was hard to understand.

4.1 Internal Testing

Through the process of developing the educational game, an internal collaborator testing was set up, where participants could test the developed game parts and provide feedback about the usability of the menus, the level of difficulty, the gameplay elements and feeling of the game. For this early a set of strict guidelines are set up. As the participants are older people the main concern at this stage are - the difficulty of the game, the overall clearness of the message and evaluation of the different game parts. The participants were given the game and left to test it out at their pace. They were given an online questionnaire containing both open ended questions evaluating the experience, as well as questions regarding their play setup - using a computer, table, phone, as well as the maximum reached level.

The main point that participant feedback focused on was a balance between challenge and user interest and to facilitate that a gradual increase in difficulty is introduced for each successfully passed level. This increase is tied to the basic ideas present in the simplified mathematical modeling of infection diseases, as presented in the Susceptible, Exposed, Infectious, or Recovered (SEIR) model (Li and Muldowney, 1995). These types of models are used for predicting the possible spread, total number of infections, the time needed for the disease to die down, etc. Taking inspiration of these types of models, we base the increase in difficulty of the game to a number of factors:

- The chance of spreading the infection - represented by the stochastic chance of spawning an infected person. This chance becomes higher with each successful level and is capped after a certain values
- Time to recover - represented by the time spawned people taken to the hospital would become healthy, lowering the number of infected in it
- Number of hospital beds and number of possible infected in society, before the spread becomes too much. This is represented in the game as lowering values, making it harder for the player to achieve the a positive level outcome

The amount by which these values increase or descries, as well as the caps to how much they can change are set, after a number of testing sessions, ending with participant feedback and discussions.

Another important factor of this initial internal testing is providing a easy to learn and use controls and menus for the game. Early on it was chosen that the game needs to be playable in a web browser, with an additional version for mobile and touch screen devices. This influenced the design of the interactions with the game, which mostly consist of swipes and presses. Both the mechanic of catching the infected people and opening and closing infrastructures are designed to be used with just presses and swipes. All menus are also designed to be easily navigated, with only button presses and dragging motions.

4.2 Teacher Feedback

Once a stable internal prototype is created, the next step is an evaluation by a primary school teacher. This evaluation is done so feedback can be given on any possible problems or places where children might find context hard to understand or navigate. In addition, parts of the game that need to be added or changed can be identified, to make the game better suited as a possible part of a study curriculum. The evaluation guidelines given to the teacher were more relaxed - they could test the prototype and use a think-aloud method for asking questions and giving feedback to their experience.

The teacher is experienced in teaching students between 10 and 13 years old and is used to implementing activities, games and participation experiences in the day to day curriculum. After analysing the game a number of points were given about the usability, ease of understanding and lessons that can be learned from it. A number of concerns are given for the possibility that students can get incorrect understanding of the spread of infections or how the different measures would change the spread. In addition, it is pointed out that the reliance of images and smaller amount of text, could make understanding and getting into the game's flow a problem. Finally, some of the visualizations in the game are pointed out as either being too hard to understand or posing a risk of stressing out the students. To address these concerns a number of improvement are made to the experience, to contextualize and refine its visuals and messages.

The main changes made from this feedback is the addition of "How To Play" (Figure 4a) section to the start menu of the game, as well as an extended visual tutorial (Figure 4b), which runs users through the main parts of the game and explains how they function and what is required. In addition, the main playable character is changed to a bed, where infected people can be cough and send to the hospital. This is made to make it less stressful to children and lower the association to ambulances and emergency situations. The interface is also made more reactive, with the implementation of additional visual cues and sound effects to signal to children that there are problems.

4.3 Student Feedback

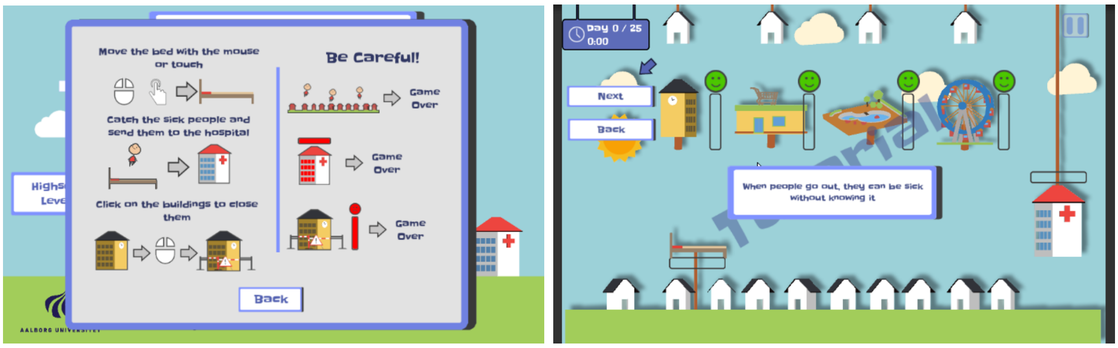
As part of the evaluation a number of students from third, fourth and fifth grade were shown the prototype and could try it out. For the evaluation the teacher first would show the game to the students and explain the overall structure and goal. The students then play the game, initially with the teacher as a facilitator and later by themselves. Once they felt that they had played enough the teacher asked the whole class what were their thoughts and questions.

The third grade students are shown to be receptive to the overall message of the application with comments like - *"If you close schools not many people will be infected. It fits that it got better in Denmark when we closed the schools"* and *"You lose, if you close things for too long"*. It is also shown that there is still some confusion, about the rate at which the infection spreads - *"It's a strange game because it's mega easy to get infected in that game. It doesn't go that fast in reality"*. The game needs to communicate better the generalization of the infection spread from real life to game form and what simplifications are used.

Students from fourth and fifth grade were testing the application, from a point of view of using it as a source to spread awareness. Students had observations on the messages communicated by the prototype - *"You get isolated at home. It is only if things have gone awry that you get to the hospital"*, as well as the need to position the game as part of a larger contextual explanation of infection spread - *"It shows nicely enough how it develops, but if you had not been told in advance that it was a model of infection spread, and have just played the game, you probably would not have caught it. It requires that you have been told the meaning of the game from the start"*. An interesting insight in the students' understanding of infection spread, many comments were made about the need for differentiating between different groups of people - older, younger or ones with pre-existing conditions and how some are more susceptible, than others. Comments like *"It does not show at all how bad it can be for other people. It does not show that people are different"* and *"It's weird if they come down from their home, then to school and then down to another home. Is it their grandparents' home - so they can infect them?"*, show that a better separation between the visualized people and houses needs to be done, so the idea of not going out and staying home to lower infection rates can be more easily communicated.

Overall the even it this early prototype stage, the game has been shown to produce a lot of discussion on the topic of infection spreading and how to prevent it in a sustainable way. By seeing the consequences of their decisions in each level, students could get a better understanding of what was shown and try to do better. A number of problems and possible optimizations are extracted from the students feedback. The most important take always can be summarized as:

- The simplification of the real world infection spread, to a simple game form needs to be explained in bigger detail - what are the houses representing, what are the closed and open facilities representing, why it's important to have some infected going to the hospital, which it's important to not let the infection spread too much.
- There needs to be a separation between different groups of people - the ones more vulnerable to the effects of a possible infection and the ones less vulnerable. Different measurements can be employed to address different people.
- Make the experience more personal - children want to see familiar things so they can empathise, with what's unfolding on the screen.
- A larger study context needs to be provided for the game experience. It can be used as a part of a infection prevention study, with other similar experiences.



(a) (b)

Figure 4: Screens added after the initial testing by the teacher - a "How to Play" screen (Figure 4a), which can be easily access from the start menu and would give a starting understanding of what is the main idea of the game. The second screen is an interactive tutorial (Figure 4b), which gives a deeper look on the different system. The tutorial cannot be skipped the first time the game is started.

5 NEXT STEPS

Because of lack of long term testing and quantitative data the current study presents just a initial exploration, which will be build upon in consecutive studies. A number of next steps are suggested for the development of the application and its position in a possible educational package. Further work with teachers would be made to create a study curriculum comprising of lectures on the topic of infection spread and prevention. These lectures will be followed by a number of animated shorts presenting every day scenarios where people could stop the spread of a infections disease by following preventive recommendations, such as social distancing, avoiding contact, washing their hands and limiting traveling. The presented game prototype will be followed by a number of additional interactive applications and physical boardgames around the same ideas. Children would be able to play these games both together with teachers, as well as alone. After the activities the knowledge of students on the topics will be tested with a number of assignments and discussions. This educational package will be available online for use by teachers.

6 CONCLUSION AND FUTURE WORK

In this paper, we presented the first steps for creating a educational game for children between 10 and 13 years old, in the topic of infection spread prevention. We build the application with the main idea of choices and consequences, where a balance between preventing infection spreading, shortages of hospital beds and preserving the population's morale needs to be found. To facilitate the idea of choices and consequences, the application contains extensive post-game statistical summaries, which can be used to reflect on the choices and how they have affected the outcome of the game.

Initial testing of the prototype was made as a combination of internal developer testing, teacher evaluation and student feedback. A number of improvements were made to the application as a result of these tests - mainly an better visual representation of the game world, an implementation of tutorials, more reactive user interfaces and menus. The application has proven to facilitate discussion between students around infection spread and interest and interest in the topic.

As a next step a structured user testing is prepared for students, where statistics like amount of time played, maximum level reached, positive versus negative outcomes reached, as well as hospital space used, amount of days each infrastructure is closed, amount of missed infected people, would be analyzed to better suit the game to the user group. In addition, a mobile version of the game would be prepared, as well as implementing all the feedback from the initial round of feedback.

ACKNOWLEDGEMENTS

This work was partially funded by the The Novo Nordisk Foundation, grant no. NNF20SA0063089. This funding is gratefully acknowledged.

REFERENCES

Castro-Sánchez, E., Kyratsis, Y., Iwami, M., Rawson, T. M., and Holmes, A. H. (2016). Serious electronic games as behavioural change interventions in healthcare-associated infections and infection prevention and control: a scoping review of the literature and future directions. *Antimicrobial Resistance & Infection Control*, 5(1):34.

Chow, C. Y., Riantiningtyas, R. R., Kanstrup, M. B., Papavasileiou, M., Liem, G. D., and Olsen, A. (2020). Can games change children's eating behaviour? a review of gamification and serious games. *Food Quality and Preference*, 80:103823.

Clack, L., Hirt, C., Wenger, M., Saleschus, D., Kunz, A., and Sax, H. (2018). Virtue-a virtual reality trainer for hand hygiene. In *2018 9th International Conference on Information, Intelligence, Systems and Applications (IISA)*, pages 1–2. IEEE.

Eley, C. V., Young, V. L., Hayes, C. V., and McNulty, C. A. (2019). Evaluation of an e-learning platform for educators to improve education around infection prevention and antibiotics. *Technology, Pedagogy and Education*, 28(5):485–501.

Govindan, B. (2018). Bacterial survivor: an interactive game that combats misconceptions about antibiotic resistance. *Journal of microbiology & biology education*, 19(3).

Hale, A. R., Young, V. L., Grand, A., and McNulty, C. A. M. (2017). Can gaming increase antibiotic awareness in children? a mixed-methods approach. *JMIR Serious Games*, 5(1):e5.

Huizenga, J., Ten Dam, G., Voogt, J., and Admiraal, W. (2017). Teacher perceptions of the value of game-based learning in secondary education. *Computers & Education*, 110:105–115.

Jacob, M. and Wiseman, R. (2020). Can you save the world. https://martin-jacob.itch.io/can-you-save-the-world. Accessed: 2020-08-31.

Javora, O., Hannemann, T., Stárková, T., Volná, K., and Brom, C. (2019). Children like it more but don't learn more: Effects of esthetic visual design in educational games. *British Journal of Educational Technology*, 50(4):1942–1960.

Kang, Y.-S. and Chang, Y.-J. (2019). Using a motion-controlled game to teach four elementary school children with intellectual disabilities to improve hand hygiene. *Journal of Applied Research in Intellectual Disabilities*, 32(4):942–951.

Korchi, A., Dardor, M., Messaoudi, F., and Mabrouk, E. H. (2020). Progression of a serious game difficulty from a playful and pedagogical point of view: Analyze and representation. *Education and Information Technologies*, pages 1–11.

Lau, H. M., Smit, J. H., Fleming, T. M., and Riper, H. (2017). Serious games for mental health: are they accessible, feasible, and effective? a systematic review and meta-analysis. *Frontiers in psychiatry*, 7:209.

Li, M. Y. and Muldowney, J. S. (1995). Global stability for the seir model in epidemiology. *Mathematical biosciences*, 125(2):155–164.

Lu, A. S. and Kharrazi, H. (2018). A state-of-the-art systematic content analysis of games for health. *Games for health journal*, 7(1):1–15.

LuluLab (2020). Covid-19 educational game. https://lululab.org/educationalgames/covid-19-game. Accessed: 2020-08-31.

Malik, A., Sabharwal, S., Kumar, A., Samant, P. S., Singh, A., and Pandey, V. K. (2017). Implementation of game-based oral health education vs conventional oral health education on children's oral health-related knowledge and oral hygiene status. *International Journal of Clinical Pediatric Dentistry*, 10(3):257.

Molnar, A. (2017). Children as agents of change in combatting antibiotic resistance. *Journal of health services research & policy*, 22(4):258–260.

Molnar, A. and Kostkova, P. (2018). Learning about hygiene and antibiotic resistance through mobile games: Evaluation of learning effectiveness. In *Proceedings of the 2018 International Conference on Digital Health*, pages 95–99.

Nugroho, S. M. S., Utama, A. S., Hariadi, M., Yuhana, U. L., and Purnomo, M. H. (2018). Heirdom: Multiple ending scenario game for mathematics learning using rule-based system. In *2018 International Conference on Computer Engineering, Network and Intelligent Multimedia (CENIM)*, pages 192–197. IEEE.

Observable (2020). People of the pandemic. https://peopleofthepandemicgame.com/. Accessed: 2020-08-31.

Ohannessian, R., Yaghobian, S., Verger, P., and Vanhems, P. (2016). A systematic review of serious video games used for vaccination. *Vaccine*, 34(38):4478–4483.

Suppan, M., Gartner, B., Golay, E., Stuby, L., White, M., Cottet, P., Abbas, M., Iten, A., Harbarth, S., and Suppan, L. (2020). Teaching adequate prehospital use of personal protective equipment during the covid-19 pandemic: Development of a gamified e-learning module. *JMIR Serious Games*, 8(2):e20173.

Tancred, N., Vickery, N., Wyeth, P., and Turkay, S. (2018). Player choices, game endings and the design of moral dilemmas in games. In *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts*, pages 627–636.

Taub, M., Azevedo, R., Bradbury, A. E., and Mudrick, N. V. (2020). 9 self-regulation and reflection during game-based learning. *Handbook of Game-Based Learning*, page 239.

Tuovinen, J. (2020). Unusterra. https://github.com/jarkkotuovinen/UnusTerra/. Accessed: 2020-08-31.

Wehbe, R. R., Mekler, E. D., Schaekermann, M., Lank, E., and Nacke, L. E. (2017). Testing incremental difficulty design in platformer games. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, pages 5109–5113.

Young, V. L., Brown, C. L., Hayes, C., and McNulty, C. A. (2019). Review of risk communication and education strategies around food hygiene and safety for children and young people.