2021 European Conference on Computing in Construction
Online eConference
July 26-28, 2021

DIGITAL COMMUNICATION TECHNOLOGIES TO SUPPORT END-USERS LEARNING FOR A SAFE RETURN TO SCHOOL DURING COVID-19

Sara Comai[1], Silvia Costa[1], Silvia Mastrolembo Ventura[1], Davide Simeone[2], Elisa Bertuzzi[1], Giulia W. Scurati[3], Lavinia C. Tagliabue[1], Giorgio Vassena[1], Francesco Ferrise[3] and Angelo L. C. Ciribini[1]
[1] Dept. Of Civil, Architectural, environmental Engineering and Mathematics, University of Brescia, Italy
[2] Dept. of Civil, Construction and Environmental Engineering, Sapienza University of Rome, Italy
[3] Dept. of Mechanical Engineering, Politecnico di Milano, Italy

ABSTRACT

The paper provides a support in the definition of COVID-19 protocols in order to allow the safe re-opening of an educational building. It also derives a reusable approach extendable to other building typologies. The integrated adoption of multiple simulation-oriented technologies is investigated. A case study is considered, where crowd simulation, agent-based simulation and communication tools have been integrated with a hybrid approach. By means of computer games, the adoption of which is within the scope of this paper, end-users can experience school use processes within a virtual environment (1) contributing to the realism of the simulation and (2) obtaining useful information regarding the protocols in force to reduce COVID-19 risks.

INTRODUCTION

The pandemic emergency due to SARS-CoV-2 has made occupancy and behaviour analyses a crucial topic of the international research on building performance. Educational buildings are among the most impacted ones by the coronavirus pandemic, with distance learning providing only a palliative solution to the education necessities of students. The paper describes a case study where crowd simulation, agent-based simulation and communication tools (i.e., training videos, interactive mini-games, videos and formative survey) have been integrated with a hybrid approach in order to train end-users for a safe return to school. Moreover, potentially critical behaviours of students have been identified and new rules have been imposed to minimise the risk of spreading COVID-19.

The SARS-CoV-2 effect in teaching and learning activities

The COVID-19 pandemic has had a strong impact on teaching and learning activities. In Italy, for example, the critical situation forced Italian schools to close from February 2020 to September 2020, changing the teaching methodology from face-to-face to distance learning. Previous studies show that the COVID-19 crisis, as well as the measures taken to contain the pandemic curve, had affected student learning and children's performance with short- and long-term effects, negatively impacting on skills acquisition (Di Pietro et al., 2020). For these reasons, during lockdown months, analyses have been performed in order to reorganise school activities and use scenarios with the aim to allow face-to-face teaching from September 2020.

Within such a context, the Italian government developed protocols to allow school re-opening ensuring COVID-19 containing, which include:

- social distancing in both circulation paths and learning spaces of educational buildings;
- mask wearing in circulation paths;
- body temperature checking before school access through thermo-scanner (37.5°C is the maximum temperature allowed);
- frequent hands disinfection with a hydro-alcoholic solution and washing;
- micro-community organisation and segmentation;
- regular and adequate room ventilation.

In addition to the protocols issued by the Italian government, two guidelines have been also issued by the so-called Technical Scientific Committee (CTS). These technical documents indicate the behavioural rules that end-users, teachers and students in particular, have to follow in learning spaces. Particularly, the protocols contain rules regarding interpersonal distances and maximum number of people allowed in classrooms and in circulation paths.

The first guideline was published in May 2020 (Official Report, n.82, 2020) and determined that at least 1 meter of interpersonal distance must be respected between end-users, both sitting at school desks or in circulation paths (i.e., dynamic meter). The second protocol was released in July 2020 (Official Report, n.94, 2020), with the aim to facilitate school directors to guarantee in-presence teaching activities and determine the observance of 1 meter of interpersonal distance in classrooms (i.e., static meter). Nevertheless, both technical documents establish that students over six years old must wear face masks for movements among circulation paths.

Simulations of end-users' activities in a virtual environment

In the last years, crowd simulation technology has been more and more adopted in the design phase in order to predict occupancy of indoor spaces. In the Architecture, Engineering, Construction and Operation (AECO) field, this approach is often used to analyse pedestrian movement inside extensive buildings (i.e., stations, shopping malls, airports) (Sung et al., 2004 and Lovreglio et al., 2018). Nevertheless, some research has applied crowd simulation in other building typology, such as educational facilities (Mastrolembo Ventura et al., 2016). On the other hand, educational facilities imply the analysis of more structured use processes than other building typologies. In this context the Agent Based Modeling limits emerge. Moreover, the need of reaching high levels of realism of simulated phenomena has led, in the last 10 years, to hybrid systems that integrate agents (BOTs), multiple players (avatars) and smart narratives, frequently supported by agents progressive training using reinforcement learning techniques (Taylor et al., 2014).

Although the application of crowd simulation to pandemics control strategies is quite unexplored, there are some primitive studies that analyse the required steps in order to secure to safe re-opening schools (Comai et al., 2020) and some useful pre-pandemic research dealing with aspects that are relevant for epidemics and related risk assessment, such as social distancing and exposure time (Harweget al., 2020).

In the presented research these simulation technologies have been integrated with additional digital technologies in order to create a communication environment where children can be involved effectively in order to be trained about in-force protocols. These communications have been important considering risk assessment, and therefore perception, is influenced by numerous individual, social, cultural and contextual factors (Cori et al., 2020). In the last decade, technology education has been established as a new approach for all stages of education, in particular to children and teenager. Computer games are an effective and highly motivational educational tool that has proved to be capable of changing users' attitudes and raising awareness in a great variety of field, including healthy lifestyle promotion (DeSmet et al., 2014), pro-social behaviors (Calvo-Morata et al., 2020) and also for teaching hygiene principles (Kostkova et al., 2010). Game principles are also useful for everyday activities, planning, and organising tasks in a playful way (Szabo et al., 2020).

Content of the paper

The research work described in this paper has been developed adopting an existing school building, located in Milan (Italy) as a case study (Comai et al., 2020). The selected building accommodates students from 2-to-10 years old and consists of three floors above ground and one semi-basement. In the semi-basement the kitchen and the canteen are located; the ground floor comprises common spaces such as the atrium and the gymnasium, the nursery classrooms (4-5 years old children) and the kindergarten classroom (2-3 years old children). In the first floor it is located the nursery room for 3 years old children, while the second floor contains the classrooms of the primary school (6-10 years old students).

In order to narrow the scope of the research down, a target group (i.e, 6-to-10-year-old students) has been considered. Training videos and interactive games based on crowd and agent-based simulations have been prepared to support the re-opening process, with the aim to analyse the targeted end-users' distribution flows in circulation paths (i.e., atrium and corridors). The main objective of adopting simulation-based computer games as communication tools has been to develop and promote the correct behaviours among end-users in order to train them in following the COVID-19 protocols in force and to avoid critical situations of overcrowding.

The continuous collaboration with the school director, the teaching staff and Occupation Medicine made it possible to understand the real problems that might have affected the application of COVID-19 protocols and to propose effective solutions. In this context, this document mainly presents the last phase of the research, namely the different types of communication tool for promoting a correct and safe behaviour.

RESEARCH METHODOLOGY

The presented research work has been developed in the last months with the clear intent of providing support in the definition of COVID-19 protocols to a real case study and contemporarily derive a replicable approach appropriate for other schools but also extendable to other building typologies.

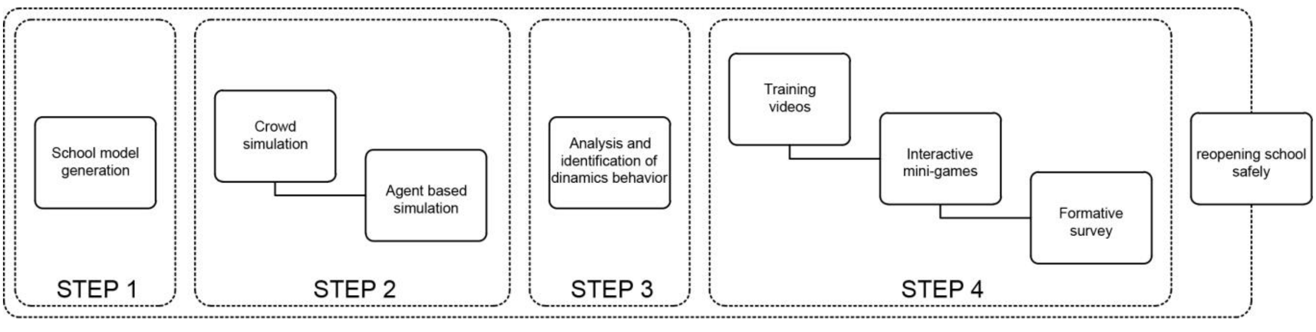

Figure 1: Research phases

Four different phases can be identified in the organisation of the research (Figure 1):

- creation of the building information model: this preliminary phase includes the development of the school building parametric model;
- simulation phases: in this phase preliminary crowd simulations have been developed to calibrate the intended use scenarios and agent-based simulation have been adopted to assess the behaviour of single students;
- children behaviour: analysis and identification of dynamic behaviour;
- communication tools: in this phase new digital technologies have been used for effective communication of the simulated use processes to the targeted end-users. Training videos, interactive mini-games and a formative survey have been generated to communicate COVID-19 protocols' rules to teachers, students and their families.

The exchange files took place in a traditional way using email and a cloud environment.

The first step was essential to know the state of the art of the school building and to carry out preliminary analyses related to the available learning and circulation spaces. Once the building information model was created (Comai at al., 2020), each floor was exported in the IFC neutral data format in order to be used as a basis for crowd and agent-based simulation as well as for the development of training videos and mini-games.

Creation of the building information model

The first methodological step involved data collection concerning the state of the art of the school building. The school director provided the research team plants and elevations of the building in a .dwg format. Moreover, in order to acquire a three-dimensional geometry and georeferenced photographic documentation, an innovative Heron mapping system was used through an indoor Mobile Mapping Survey (iMMS). A 3D point cloud model was generated and used for the extraction of measures that would not be available otherwise based on the 2D documentation originally provided by the school director (Figure 2).

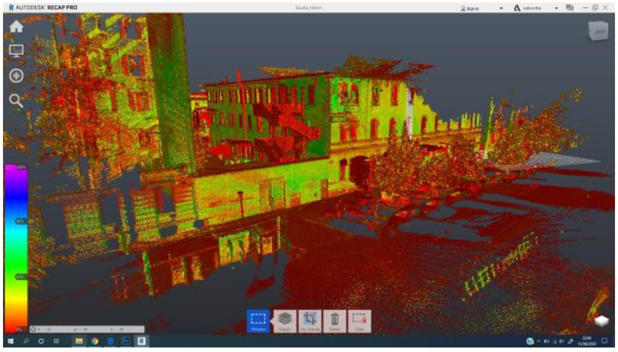

Figure 2. 3D point cloud model of main elevation of the school

Subsequently, a three-dimensional parametric model was manually generated by using the Autodesk Revit BIM authoring platform. The model was then used as a basis for analysing classrooms' functionality (e.g., maximum number of students allowed in each classroom) and for developing use processes' simulations in circulation paths in compliance with the COVID-19 protocols in-force at the time of the case study's development.

Simulation phases

In order to support the re-opening process, tools for the simulation of people flows have been developed at both crowd and agent-based levels. These simulations (Figure 3) describe children movements in a collective scenario. In particular:

(1) for students of all three levels of education, entrance and exit processes from the building have been studied;

(2) for primary school students, who are within the scope of this paper, also the lunch break movements have been considered in the simulations.

These analyses allowed the research team to calculate the maximum number of students acceptable inside the building for a specific activity according to the COVID-19 protocols. Additionally, these data were used to organise school timetables for students' entrance and exit from the building considering the need to guarantee a minimum interpersonal distance.

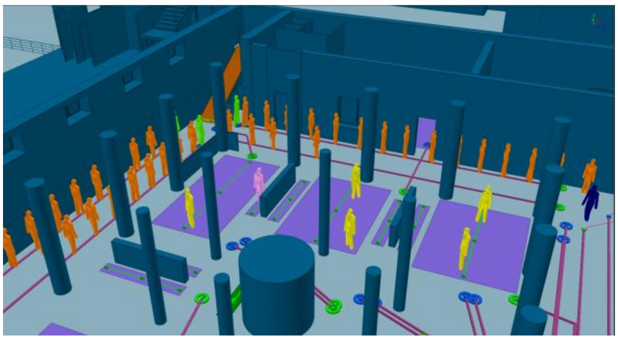

Figura 3. Simulation in the collective scenario

Oasys MassMotion has been adopted as crowd simulation tool. In order to obtain a more realistic crowd simulation, the software settings have been implemented with real movements speed of children (m/s) and with the meter of interpersonal distancing imposed by the national CTS. To allow users' safety during entrance and exit phases, the large atrium of the school has been divided in different zones (Figure 4). The first area is in proximity to the building entrance and hosts the thermo-scanner checkpoint. In this zone, the body temperature of each student is measured, allowing his/her entrance to the schools only if it results lower than 37.5°C. The next zone, a few meters away from the previous one, is equipped with an appropriate hand disinfection dispenser.

The remaining space in the atrium is divided into two additional zones called "waiting" and "circulation" areas. These areas facilitate the organisation of students in groups and allow the coexistence of children of different educational levels:

- in the central part of the atrium, five play areas for the nursey students;
- three zones have been selected to facilitate the organisation of primary school students during entrance/exits flows;
- circulation paths link the previous areas.

In each zone, primary school students, teachers and all the end-users with an age greater than 6 years old must wear a mask and maintain social distancing.

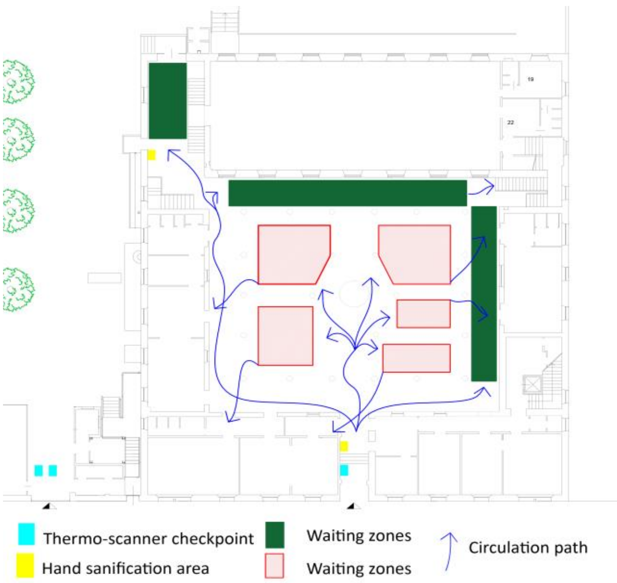

Figure 4. The atrium organisation in zones

In order to reach a higher level of accuracy of the simulation and of the related emerging use phenomena, it has been chosen to implement a behavioural simulation model within a game engine (Unity3D). In this environment it is possible to integrate (Figure 5):

- the building information model of the educational facility, including furniture and COVID-19-related equipment;
- agents (BOT) representing end-users involved in the use process;
- a process controller able to coordinate agents' behaviour to improve adherence to the evaluated scenario;
- characters directly controlled by real users (avatars), with a dedicated first-shooting interface.

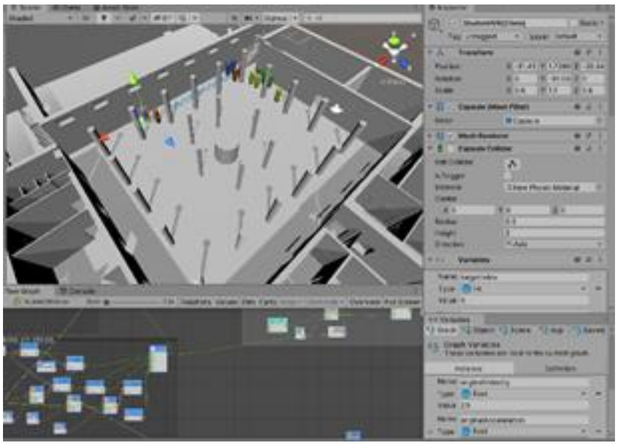

Figure 5. The behavioural simulation of school use as simulated in Unity3D

This integration allows simulating more complex behaviours and interaction among agents than crowd simulation, while the process controller assesses the status of the system and steer behaviours accordingly to objectives and activities of the intended use scenario.
By means of a simplified user interface, it is also possible to involve real users in the simulation/serious game, and to allow them to move within the school, interact with agents and other avatars, and receive suggestions and objectives from the process controller. The direct involvement of real users, in particular children and teachers, allows to improve the level of realism of the simulation. In this way, introducing decisions, movements and actions taken by the player are introduced; moreover, it helps the understanding of the protocols and measures adopted for COVID-19 risk reduction because it provides preliminary training.

Children behaviour

After the simulation phase, there was a need to train users to avoid critical behaviours within the school. The cooperation with Occupational Medicine has been the crucial point in order to identify critical behaviours. The typical day was divided into four phases in order to map the related use processes: entrance/exit, lesson's time, break time and lunch break. In each phase, behaviours that usually occur in the schools have been analysed and selected according to the potential risk of transmission of the infection. Instructions have been identified for each potentially dangerous behaviour according to containment measures of COVID-19.

Beyond social distancing and frequent hygiene practice as hands sanitising after sneezing or coughing, the focus has been on behaviours that, in normal situations, people instinctively do. This paper will focus on two situations, presenting their problem and the resolution of it. (1) One of the most common situations in the classroom is the sharing of stationery materials (pencils, erasers), for this reason it is necessary for teachers to slavishly control the students. Each class must have a common box, under the control of the teacher, containing writing materials to support children needs. Once an object from the box has been used, it must be placed in a second box which will be sanitized at the end of the day. Whereas, if the sharing of material took place between two students, the teacher is required to disinfect the hands of the children involved and disinfect the shared object. (2) Another common situation is helping children to put on coats, zipping up or tie their shoes. In this case, the people involved must wear masks and must disinfect their hands before and after helping.

Each potentially dangerous behaviour has been reported in a table. The problem and the resolution were described and it has been identified at what phase of the school day it could occur. In Figure 6, the conceptual framework created to have an overview of the situation is shown.

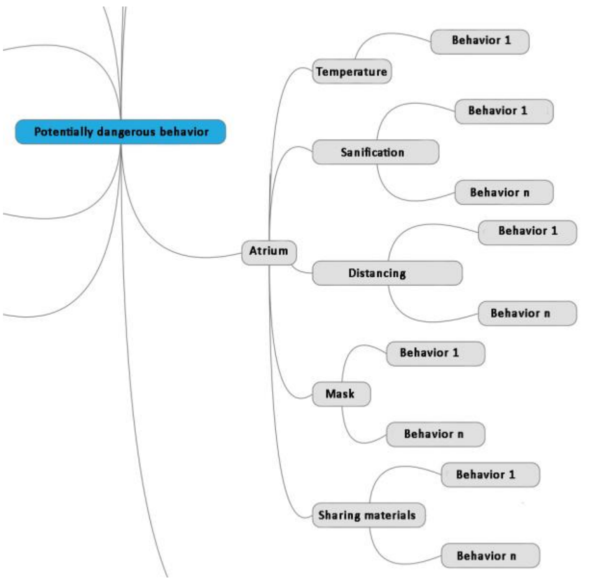

Figure 6. A conceptual framework of potentially dangerous behaviour

Communication tools

The use of new communication technologies (training video, interactive game) in childhood education is becoming more and more relevant. Moreover, the COVID-19 emergency has pushed the use of new digital methods (Figure 7). These new digital technologies help to build effective communication environments, in fact, they stimulate the child's curiosity and make him have fun (Ar Rosyid et al., 2018)). With the authorisation of the school director, it was decided to produce training videos and interactive mini-games to communicate new rules of conduct to be followed to return to school safely, which are the results of the simulations previously described. Furthermore, a critical situation questionnaire was created to convey information on specific behaviours.

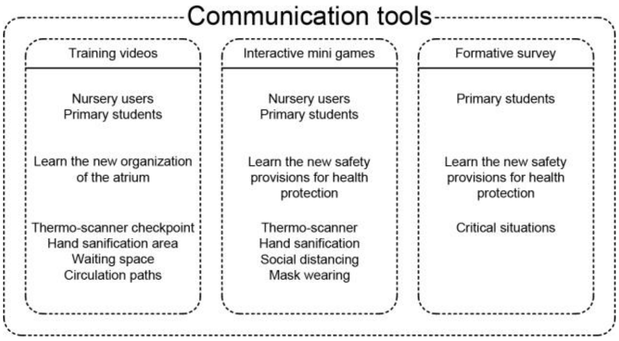

Figure 7. Communication tools and their use

In order to support primary and nursery students to come back to "in-presence" teaching activities, two training videos typology were generated. These videos were composed by different media contents, which comprise simulations of correct behaviours to maintained in collective scenarios showing the new identified circulation paths to avoid over-crowded conditions (Figure 8). Additionally, these videos were integrated with formative sign, indicating the appropriate conduct to maintain inside and outside the school. Considering the different capabilities between primary students and nursery users, different users' group were targeted with dedicated videos (Figure 9). These communication method was chosen because reading and viewing images accompanied by a voice guidance creates a stimulating context for the child's learning. In addition, the COVID-19 emergency has forced schools to use new digital methods by promoting tools that are commonly already used normal in other fields.

Finally, these videos were accompanied by a voiceover recording which explains, with friendly and engaging rhymes the new behavioural rules.

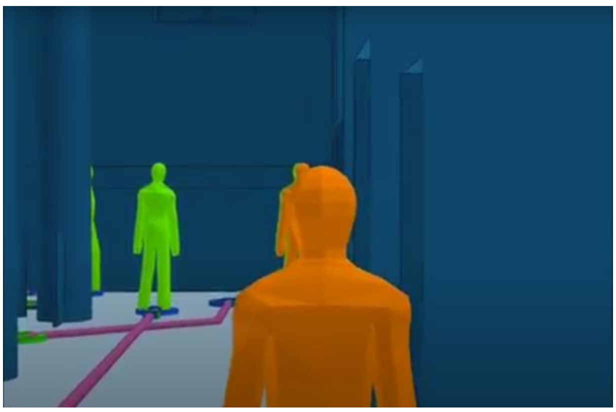

Figure 8. Screenshot of the simulation on the circulation paths

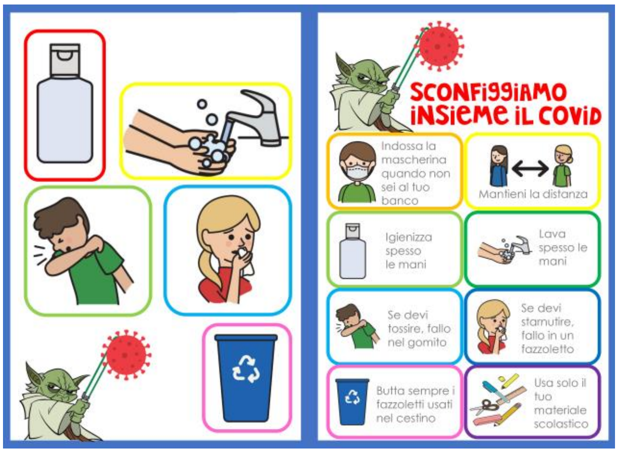

Figure 9. Educational images. Left: sign for nursery users; Right: sign for primary students

The second communication tool developed are interactive mini games. They teach children the importance of rules to minimize the risk of COVID-19 spreading and teach the procedures to be adopted for returning to school. Each game is presented through explanatory illustrations and captions. Moreover, between one game and another, illustrated screens were developed to present situations which take place in a typical day.

Mini-games have been developed regarding the procedures to be performed before going to school and before entering the school building. Below are the three phases analysed:

- backpack preparation;
- use of thermo-scanner at the school entrance;
- hands sanitizing at the entrance.

When entering the game, the first choice that the player is required to make is the choice of the student profile. Subsequently, the first step to comply, while there are still at home, is to measure their body temperature which has to be under 37.5 °C. Next, the gamer has to prepare the backpack, then a backpack and objects around it appear on the screen. The player must drag and drop the object into the space provided. When the gamer selects the object and place it inside the backpack, a congratulatory exclamation and an explanation of why it is important not to forget the object appears on the screen. (e.g, ‘Good job! Wearing the mask is important to protect yourself from the virus’) (Figure 10).

Figure 10. Backpack preparation game

The game continues following the child in path from home to school. In this case the instructions emphasize the importance of respecting social distancing on the sidewalk at the school entrance. Upon entering the school building two games appear, the first one requires the child to approach the thermos-scanner point where the gamer must wait for a time equal to 6 seconds, the time necessary for the device to correctly measure the temperature. The second mini-game requires the sanitization of the hands: two hands full of bacteria appear on the screen and, by moving the mouse or finger over them, the gel will eliminate them (Figure 11).
The game continues automatically by showing the paths to follow in the school atrium.

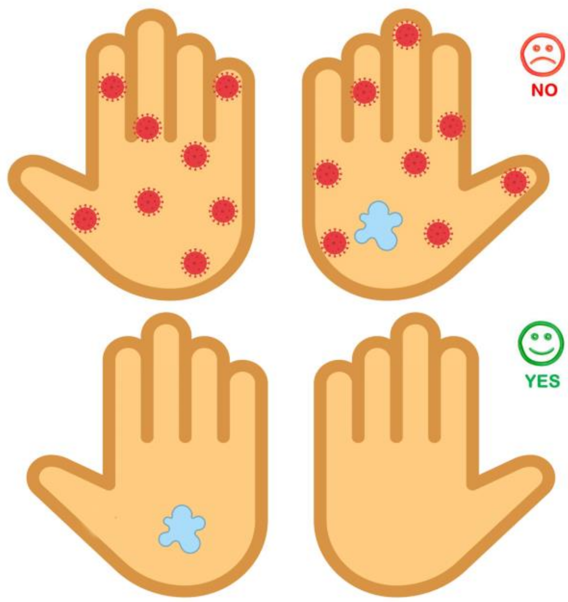

Figure 11. Hands sanitizing game

The latest communication tool developed in this research is the formative survey on critical situations that can occur in the school.

The final illustrations regard the rules to follow in common environments. Images teach children how to respect social distancing and the correct use of material (e.g., not sharing it with classmates) to prevent contamination. Similar illustrations are proposed to children in a final survey to assess their overall learning and understanding of rules.

The survey consists of a 16 multiple choice questions with four possible answers. The quiz requires a basic knowledge of containment measures adopted by Italian Government and of measures adopted by the specific school case study. The survey verifies the attitude of the children in some critical situation that can happen during the daily routine. The image in it shown rules for moving in the building and potentially dangerous behaviours.

Moreover, this tool can be useful to inform teachers on children behaviour and the safe way to act in those particular situations.

CONCLUSIONS

The paper describes a case study in which the analysis on the behaviours to be maintained within the school becomes crucial in order to re-open an existing building safely during pandemic period. Information is provided through a series of mini-games for children, explaining specific rules to follow at school (e.g., use of masks, social distancing, temperature check, hands sanitizing). The use of digital communication technologies based on images and texts accompanied by a guided conversation stimulates learning.

From the comparison with the end-users carried out in the school, some advantages of adoption this approach emerged:

- the opportunity to experience the scenario before the re-opening of the school has made it possible to improve management choices and actions based on virtual simulation;
- the distribution of mini-games and training videos, in the week before the re-opening, allowed students and operators to learn about the new provisions adopted by the school and the new behaviours to be maintained, thus reducing the learning time at the first school days;
- in the first days of school students already knew the path to follow and where to stop for temperature control and hands sanitation.

The school has started in September 2020 based on the results of the proposed analyses with the use of these new communication tools and the described digital ecosystem. The simulations developed were fundamental for the school director, allowing the school reorganisation in a functional way, without neglecting any aspect. Each choice taken, derived from a broader reasoning linked to needs of end-users, deadlines to be respected and COVID-19 provisions.

The presented work supports in the definition of COVID-19 protocols that can be adopted in a school building and related use scenarios, but the same methodology could be also implemented in other works, leisure environments and building typologies. This is possible since the skeletons of this study reflects the good rules of behaviour for reducing the spread of the virus. In such scenario it will be necessary to retrace the proposed methodology and customise it according to the needs of the specific case.

In future works, serious games based on the simulations and the games reported in this paper could be developed with the aim of teaching new rules of behaviour. In fact, gamification represents an innovative and promising technology for stimulating learning. This technology is suitable for any age, but to be effective it must be developed according to player's needs. Indeed, two different contents were developed for nursery and elementary children, in order to make them more understandable and stimulating. These tools could be designed to be used through both immersive and non-immersive virtual reality technologies, with the purpose to educate final users for a safe return to school. Another future work could be related to the analysis of the data obtained interviewing the teaching staff on how communication tools have impacted on children's behaviour.

ACKNOWLEDGMENTS

The authors would like to acknowledge the school director and the teaching staff for the collaboration and the availability to analyse the case study. Moreover, the authors would like to mention Oasys Software and CSPFea for the technical support they provided to the research team.

REFERENCES

Ar Rosyid, H., Palmerlee, M., Chen, K. 2018. Deploying learning materials to game content for serious education game development: A case study. *Entertainment Computing*, https://doi.org/10.1016/j.entcom.2018.01.001

Calvo-Morata, A., Alonso-Fernández, C., Freire, M., Martínez-Ortiz, I., & Fernández-Manjón, B. 2020. Serious games to prevent and detect bullying and cyberbullying: A systematic serious games and literature review. Computers & Education, 157, 103958.

Comai, S., Costa, S., Mastrolembo Ventura, S., Vassena, G., Tagliabue, L.C., Simeone, D., Bertuzzi, E., Scurati, G.W., Ferrise, F., Ciribini, A.L.C. Indoor mobile mapping system and crowd simulation to support school reopening because of covid-19: a case study. Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLIV-3/W1-2020, 29–36, https://doi.org/10.5194/isprs-archives-XLIV-3-W1-2020-29-2020 , 2020.

Cori, L., Bianchi, F., Cadum, E., Anthonj, C., 2020. Risk Perception and COVID-19. Int J of Environ Res Public Health. 2020;17:E3114

DeSmet, A., Van Ryckeghem, D., Compernolle, S., Baranowski, T., Thompson, D., Crombez, G., ... & De Bourdeaudhuij, I. (2014). A meta-analysis of serious digital games for healthy lifestyle promotion. Preventive medicine, 69, 95-107.

Di Pietro, G., Biagi, F., Dinis Mota Da Costa, P., Karpinski, Z. and Mazza, J., The likely impact of COVID-19 on education: Reflections based on the existing literature and recent international datasets, EUR 30275 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-19937-3, doi:10.2760/126686, JRC121071, (2020). https://ec.europa.eu/jrc/en/publication/likely-impact-COVID-19-education-reflections-based-existing-literature-and-recent-international. As of 24 November 2020.

Harweg T., Bachmann, D., Weichert, F., 2020. Agent-based Simulation of Pedestrian Dynamics for Exposure Time Estimation in Epidemic Risk Assessment. *Physics*. arXiv:2007.04138.

Kostkova, P., Farrell, D., De Quincey, E., Weinberg, J. R., Lecky, D., & McNulty, C. (2010, January). eBug-teaching children hygiene principles using educational games. In MedInfo (pp. 600-604).

Lovreglio, R., Dias, C., Song, X.,, Ballerini, L., 2018. Investigating pedestrian navigation in indoor open space environments using big data. *Applied Mathematical Modelling* 62, 499-509. doi.org/10.1016/j.apm.2018.06.014.

Mastrolembo Ventura, S., Simeone, D., Ghelfi, D., Oliveri, E., Angelo L.C. Ciribini, A. L.C., 2016. Building Information Modeling and Gamification for educational facilities. *Back to 4.0: Rethinking the digital construction industry*, 203-212. Maggioli Editore.

Official Report n. 82. May 2020. Technical Scientific Committee (CTS) Covid-19. Italian Ministry of Health.

Official Report n. 94. July 2020. Technical Scientific Committee (CTS) Covid-19. Italian Ministry of Health.

Sung, M., Gleicher, M., Chenney, S., 2004. Scalable Behaviors for Crowd Simulation. *Computer Graphics Forum 23* (Eurographics'04) 2004.

Szabo, T. G., Richling, S., Embry, D. D., Biglan, A., & Wilson, K. G. (2020). From helpless to hero: Promoting values-based behavior and positive family interaction in the midst of Covid-19. *Behavior Analysis in Practice*, 1-9.

Taylor, M. E., Carboni, N., Fachantidis, A., Vlahavas, I., Torrey L. Reinforcement learning agents providing advice in complex video games. *Connection Science*, (2014) 26:1, 45-63