BubbleMumble: A Serious Game for the Dissemination of Scientific Results in Secondary Schools

Alessandro Signa[1,2][a], Manuel Gentile[1,3][b], Sabrina Picciotto[4][c], Antonella Cusimano[4][d] and Salvatore Perna[1,2][e]

[1]*Institute for Educational Technology (ITD), National Research Council of Italy (CNR), Palermo, Italy*

[2]*Department of Engineering, University of Palermo, Palermo, Italy*

[3]*Department of Computer Science, University of Turin, Turin, Italy*

[4]*Institute for Research and Biomedical Innovation (IRIB), National Research Council of Italy (CNR), Palermo, Italy*

Keywords: Serious Game, Dissemination, GBL.

Abstract: Disseminating the scientific results of a project, especially to young audiences such as secondary school students, is a difficult task. Often the worlds of research and school are so far apart in terms of communication that there is a risk of dissipating dissemination efforts without achieving satisfactory results. Serious Games are a tool that can respond to this problem by providing a fun and effective environment that is very close to the world of young people, and that uses familiar language through which the educational content can be conveyed. In this paper, we will present BubbleMumble, a Serious Game designed and implemented to disseminate the results of the European project VES4US. We will also describe the project together with its dissemination objectives, and finally, we will present the results of an experiment on the use of the serious game involving 131 students of the secondary school.

1 INTRODUCTION

The dissemination of scientific results in research projects is a key step. It is the process by which what is achieved by academic efforts is transferred and shared both with the rest of the scientific community and with the wider non-specialist population. Traditionally, scientific dissemination takes place through presentations and publications of scientific articles in journals and conferences, channels that unfortunately often remain confined to the context of the scientific community. The need to reach a wider audience, through the planning of effective strategies and the choice of appropriate means of communication, has recently been highlighted by the European Commission in the context of the Horizon2020 Research and Innovation programme (European Commission, 2014).

As modern society continues to evolve through new paradigms of communication and social interaction, becoming increasingly intertwined with the digital world, traditional knowledge transfer patterns and learning processes struggle to keep pace (Loganathan et al., 2019). According to recent statistics, half of the European population regularly uses video games, with an average of nine and a half hours of gaming per week (ISFE, 2021). This phenomenon is not confined to Europe, and similar numbers can be observed in the United States (ESA, 2021) and China (Mcgregor, 2021). While this trend is constantly growing, the idea of using video games, their language, and features to enhance learning processes is not new. The idea itself that play is a serious matter traces back directly to Plato (Ardley, 1967).

Today, serious games (SG), i.e. games that do not have entertainment or fun as their main objective but rather educational goals (de Freitas, 2006; Charsky, 2010), are increasingly being used, also due to the results that research has produced in recent years. Although the scientific community is still divided on the impact of SGs on learning outcomes (Kalogiannakis

[a] https://orcid.org/0000-0001-5861-488X
[b] https://orcid.org/0000-0001-6288-0830
[c] https://orcid.org/0000-0001-5544-984X
[d] https://orcid.org/0000-0001-6811-5670
[e] https://orcid.org/0000-0003-2206-8172

Signa, A., Gentile, M., Picciotto, S., Cusimano, A. and Perna, S.
BubbleMumble: A Serious Game for the Dissemination of Scientific Results in Secondary Schools.
DOI: 10.5220/0011043000003182
In *Proceedings of the 14th International Conference on Computer Supported Education (CSEDU 2022) - Volume 2*, pages 467-474
ISBN: 978-989-758-562-3; ISSN: 2184-5026

et al., 2021; Subhash and Cudney, 2018; Zainuddin et al., 2020; Adžić et al., 2021), several studies show the positive impact they can have on students' engagement and motivation (Subhash and Cudney, 2018; Bakhanova et al., 2020; Papastergiou, 2009; Filsecker and Hickey, 2014; Connolly et al., 2012; Boyle et al., 2016; Hamari et al., 2016).

Another huge advantage of SGs is that they offer a complex simulated virtual environment in which to experience safe, cost-effective, and less stressful than reality. This is immediately evident in specific simulation games such as Microsoft Flight Simulator X, where the level of realism is so high that it can be used as an effective tool for training and the evaluation and study of flight-related phenomena (Kortelling et al., 2016; Karmakar et al., 2019; Mohammed and Khaled, 2021), but at the same time it is also true for games that were not created as faithful simulators. This is the case with games such as SimCity and Roller Coaster Tycoon (RCT), which started as commercial games aimed at pure entertainment and which over time have been used as virtual environments in which to experiment and learn skills and competencies transferable to real-life (Sierra, 2019; Roose and Veinott, 2017; Bereitschaft, 2021; Pramaputri and Gamal, 2019; Arnold et al., 2019).

For these reasons, it was decided to use Serious Games to disseminate the research results obtained within VES4US, a three-year project (2018-2021) funded by the Horizon 2020-Future and Emerging Technology (FET) program, that involved 6 organizations from as many European countries (https://VES4US.eu). The project aims to realize and develop an innovative platform for the efficient production of extracellular vesicles (EVs) starting from a biological and renewable culture: microalgae. The innovation introduced by VES4US lies in the intuition that microalgae could represent a natural source of EVs that at the same time is cheap, sustainable, and easily scalable at the industrial level.

It is in this framework that BubbleMumble comes to life, the Serious Game that has the task of spreading the contents of the VES4US project to students aged between 13 and 16 years old. BubbleMumble is composed of two distinct parts, two separate and independent games: BubbleMumble Kart and BubbleMumble Lab. The first one is meant to teach players about elementary biological concepts related to the world of EVs, and it does so by transporting players to a go-kart race that takes place inside a cell. The second one is set in a laboratory and it is aimed to disclose the processes of characterization and functionalization of EVs, remaining faithful to the methodological processes developed within the project VES4US.

In this work, we will deal exclusively with the second of the two games, BubbleMumble Lab, which for brevity in the following will be called just BubbleMumble. The game, once complete, has been the subject of experimentation that has involved 131 students of both lower and upper secondary school.

In the following chapters, the game will be presented, together with its design. Then the experimentation carried out will be described and results will be shown and discussed. Finally, conclusions will be drawn from the experience collected and future works will be considered.

2 THE BUBBLEMUMBLE SERIOUS GAME

BubbleMumble is a serious game designed to disseminate the activities of the VES4US project. The game, in its entirety, is composed of two independent games. The first aims to make the players aware of the biology concepts underlying the processes of vesicle generation. The second is aimed at disseminating the processes developed within the VES4US project used to characterize and functionalize extra-cellular vesicles. In this chapter, we will describe the second of these games, since it was the object of the experimentation presented in this work. The processes to be conveyed through this game are therefore the isolation of nanovesicle cultures, their functionalization, and their characterization. This entire process is determined by a very specific sequence of steps, each with its peculiar parameters. The various steps have to be carried out in a precise order and the value of the parameters involved has to be set accurately to complete the process successfully.

The idea that guided the design of this game was to consider the isolation, functionalization, and characterization production chain as a kitchen recipe, where sequencing and dosage are two essential factors. It was therefore identified the commercial video game Overcooked as a source of inspiration for the design of this portion of the BubbleMumble game. In Overcooked, the player has to work with his team to cook, plate, and serve a variety of dishes to eager customers. The main feature that makes the game extremely fun and addictive is the constant state of 'frenzy' that forces the player to sharpen his reflexes and keep his attention level high at all times. The game flow within each level is characterized by a series of simple operations (e.g. slicing a vegetable). Simple operations in series must be carried out one after the other so that the final dish can be served. The ingredients scattered around the kitchen must be

identified, collected, and used according to the recipe using the available utensils.

BubbleMumble has been designed based on the above-mentioned features to achieve the objectives of dissemination while engaging the players in fun activities. The game is set in a laboratory with all the necessary tools for the production of nanovesicles. Here the player plays the role of a young researcher. The game has two distinct modes: Internship and Production. These have different objectives: the Internship mode aims to train and tutor the player in the game environment and the concepts it conveys, while the Production mode serves to verify and reinforce what was learned during the training. In the Internship phase, under the guidance of a more experienced virtual researcher (non-player character), the player will discover the various ”recipes” that lead to the development of algae cultures and the selection of various types of nanovesicles. In Production mode, the player will have to produce the vesicles, using the recipes discovered and the tools available in the laboratory, to meet the delivery requests coming from the market. Each request is characterized by a maximum time that the customer is willing to wait to receive his order: the player will therefore have to manage the various steps of the process, even carrying out several cultures in parallel, to respond to as many requests as possible within the time limits.

2.1 User Interface

The serious game, in both modes, allows the player to move in third-person inside a three-dimensional laboratory in which there are several tables with all the instruments necessary for the procedures he/she will have to carry out. The interface has been designed keeping in mind the purpose of the game and the devices on which it will be played, namely smartphones and tablets.

For this reason, to control the character's movements there is a joystick on the left-hand side of the screen, designed to be used with the left thumb. Its counterpart, on the right, is a button that allows you to interact with the elements present in the laboratory (tools, tables, baskets, etc.). At the top of the screen, the list of steps required to complete the extraction process of the nanovesicles for the algae culture currently being carried by the character is shown. This list presents the steps in the form of intuitive icons and each of them is marked as soon as the relevant step is completed by the player. The lower part of the screen shows on the left the graphical indication of the current quality value of the current culture and on the right, there is a button that allows access to the player's notes. The notes, represented through a full-screen panel, summarize synthetically and immediately what the player has learned about the various types of microalgae present in the game and about some of the tools present in the laboratory. There are also some elements of the interface that are only present during the Production mode because they relate to game mechanics that are not active during the Internship phase. In the top left corner of the screen, there is an hourglass that indicates the time remaining before time runs out. Also displayed nearby is the player's current score for the current session. At the bottom of the screen, in the center, a list is displayed containing requests for nanovesicles from buyers. Each request is represented through characteristic icons and a slider that indicates how long the customer is willing to wait for the fulfillment of his order; during the game session, this list is continuously updated. Finally, on the left margin of the screen, an alert symbol is shown now and then, warning the player about the immediate appearance of danger inside the laboratory.

2.2 Gameplay

Each production cycle starts with the selection of algae (from 4 alternatives) from a special container and continues through multiple steps to fulfill the ”recipe” of the selected algae. Step by step, the player has to add nutrients to the culture, adjust its ph, manage its incubation, set up extraction and vesicle isolation cycles, and finally check the quality of what is obtained. The whole process, from selection to quality control, is made up of sequential tasks, each of which includes a mini-game whose score will have a direct impact on the quality of the culture. The score will be higher the more accurate the work done by the player in completing the mini-game. The overall quality of the algae culture depends on the scores obtained in each of the mini-games. If the player compromises the culture considerably by getting too low of a score, it will be degraded and discarded and the player will have to start over.

In Internship mode a non-player character will support the player during the process, highlighting the key concepts of each production step and guiding the player explicitly through the correct sequence of steps. In this phase, additional guides will be provided to the player both to facilitate his spatial orientation in the laboratory and to suggest the best way to complete each mini-game in the sequence. The aim of this mode is to provide the player with the detailed knowledge, often numerical, needed to carry out the correct steps: he/she will have to select, for example,

the right amount of vitamins for the culture medium, adjust the pH and remember whether a certain microalgae needs fresh or saltwater to grow properly. Once all the necessary steps have been completed, the quality of the product obtained is communicated to the player as soon as he inserts the mixture into a quality control machine. This machine, simulating the control on markers, homogeneity, and quantity, returns to the player a certificate containing the final judgment on the vesicles he has produced. This phase thus plays the role of the game's tutorial, in order to give the player a chance to become familiar with the dynamics and mechanics of the game. As soon as an entire production cycle is successfully completed in the Internship phase, notes about it will be added to the player's handbook, which will then always be available for consultation, in every phase of the game. During the Internship, without any game contingencies and without any time limit, the player will be able to learn, at his own pace, what is necessary to be independent and efficient in the production phase.

In the Production mode, the mechanics described above remain, but the presence of guides during the production cycle is reduced. In this mode, however, some mechanics are introduced to increase engagement and encourage the consolidation of the knowledge acquired during the apprenticeship. The player will have to satisfy the requests coming from the market, each of which will be characterized by a type of seaweed and an indication of the quantity to be delivered. Each request must be fulfilled within a time limit, after which the customer will no longer be interested in the product. Each request completed within the time limit will give the player a higher score if the customer is satisfied with the product. Customer satisfaction is influenced by the speed with which the request is completed, the quality of the compound produced, and the correctness of the vesicle isolation cycles. The player's ultimate goal will therefore be to obtain the highest possible score within the time limit of the game session in production mode, which equals 10 minutes.

To make the game less linear, and therefore more fun and engaging, during the Production mode there is a random generation of obstacles that the player must avoid in order not to lose precious time. During the course of the game, in fact, flasks containing liquid will shatter on the ground, making the area slippery and posing a frequent risk of falling to the player. In the laboratory, there are also some elements that are not strictly functional to the completion of the process but are certainly of help to the player. In fact, there are some empty tables scattered around the room that allows the player to temporarily place the algae culture he/she is holding in his/her hand, thus allowing him/her to carry out several processes in parallel. There are also baskets that allow the player to throw away or discard the held culture if it has become useless or unsatisfactory. Finally, a microscope placed on a table on the left side of the room allows the player to see the enlarged detail of his/her own culture, showing the cell bodies of the microalgae at the base of the compound.

3 METHOD

3.1 Participants

The experiment involved numerous students from different Italian schools located in the cities of X and Y. In particular, two classes from the third year of lower secondary school and four classes from the second year of upper secondary school (one from the first year, one from the second and two from the fifth) participated. Although the target design was students aged between 13 and 16, it was decided to include students from the last years of upper secondary school in order to assess the impact of the game on them. The selection of the classes was random. In total, the activities were carried out by 131 students (average age=15.69, sd=9.13), of which 49 belonged to the lower secondary school and 82 to the upper secondary school. 54.96% (n=72) of them identified themselves as female, 38.93% (n=51) as male, and 6.11% (n=8) preferred not to indicate any gender.

3.2 Materials

Students played the game using their personal mobile devices (tablets and smartphones). The Serious Game was made available on the main stores (App Store and Google Play Store) completely free of charge. The researchers gave a short presentation to the students about the basics of biology related to the world of extracellular vesicles, as well as the context of the VES4US project and the game and its purpose. Finally, a questionnaire was administered to the students in order to detect their perception regarding the usefulness of the game, the level of engagement, the concepts at the center of the dissemination objectives, the level of clarity of the instructions provided, the interest in the topics dealt with and to provide feedback on the game itself. The questionnaire consists of 22 items on a ten-point Likert scale. The items are listed in Table 1. Before answering the questionnaire, the students also answered some questions aimed at collecting demographic data such as age, gender and

Table 1: The items of the questionnaire given to the students.

Item identifier	Item
Q1	How much do you like biology-related topics?
Q2	How well did you understand the objectives of the game from the start?
Q3	How keen are you to install the game on your device?
Q4	How motivated are you to continue playing with BubbleMumble?
Q5	How useful was the Internship mode for understanding the process of vesicle production and selection?
Q6	How useful was the Internship mode in identifying the correct mix of elements for good and correct vesicle production?
Q7	How useful was the Internship mode for understanding the differences between the different types of algae?
Q8	How useful was the game in improving your ability to develop and apply appropriate time management strategies and/or tactics?
Q9	How useful was the game to get a general idea of how a research laboratory works?
Q10	How useful was the game for understanding what extracellular vesicles are?
Q11	How useful was the game in identifying the correct flow of play to make a vesicle?
Q12	How useful was the game in identifying the variables that affect the algae culture quality?
Q13	How useful was the game to associate the nutrients needed for each type of algae culture?
Q14	How engaging is the game?
Q15	How boring is the game?
Q16	How educational is the game?
Q17	How useful is the game?
Q18	How playable is the game?
Q19	How would you rate the game's graphics?
Q20	How would you rate the game's sounds?
Q21	How would you rate the game's feedback?
Q22	How would you rate the game's instructions and explanations?

school attended, together with indications of any prior study of biology.

3.3 Procedures

All the experimentation-related activities were carried out in the classroom within the school context. For each class, two researchers belonging to the working group attended the activities. They started by briefly presenting to the students the key concepts related to extracellular vesicles, the context provided by the VES4US project, the game, and its purpose. This presentation lasted an average of 5 minutes. At the end of the presentation, students were asked to download the game on their devices: to this end, students were directed to the Apple App Store or the Google Play Store, depending on the device. Before continuing the activities, it was ensured that all students had downloaded and installed the game. At this stage, the researchers helped the students by providing assistance and guidance. Once the entire class had installed the game, students were asked to begin playing the game in Internship mode and complete a full production cycle. At the end of this first cycle, students were given complete freedom on their choice of game mode and were informed that they could switch between modes (from Internship to Production and vice versa) at any time. The students then played freely for 45 minutes. At the end of this time, in order to increase engagement and ensure that everyone played in Production mode, a friendly "competition" was opened to determine who would be able to get the highest score at the end of a 10-minute session played exclusively in Production mode. At the end of this small competition, where the students competed against each other, a winner was named. Next, students were asked to fill out an anonymous questionnaire. The questionnaire was administered via the Lime-Survey web platform through the same personal devices that the students used for the game.

Table 2: Descriptive statistics of items.

Item identifier	Short Item description	mean	sd	skew	kurtosis
Q1	biology engagement	7.05	2.25	-0.92	0.59
Q2	initial goal comprehension	6.62	2.62	-0.53	-0.51
Q3	intention to install	5.75	3.02	-0.27	-1.18
Q4	intention to play	5.64	2.98	-0.17	-1.26
Q5	production understanding	7.03	2.50	-0.82	0.02
Q6	mix understanding	6.98	2.39	-0.87	0.20
Q7	algae understanding	6.34	2.65	-0.49	-0.64
Q8	strategy time improving	6.00	2.73	-0.43	-0.85
Q9	labwork improving	7.19	2.18	-0.85	0.48
Q10	vescicles improving	6.18	2.44	-0.55	-0.39
Q11	flow of play	6.29	2.53	-0.69	-0.34
Q12	variables identification	6.33	2.61	-0.64	-0.47
Q13	nutrients needed	6.34	2.50	-0.52	-0.34
Q14	engaging	6.77	2.46	-0.73	-0.19
Q15	boring	4.98	2.67	0.36	-0.77
Q16	educational	7.48	2.23	-1.09	0.87
Q17	useful	6.42	2.59	-0.64	-0.40
Q18	playable	6.37	2.46	-0.54	-0.38
Q19	graphic	6.09	2.35	-0.60	-0.48
Q20	sound	5.66	2.78	-0.31	-0.90
Q21	feedback	6.40	2.54	-0.59	-0.32
Q22	instructions and explanations	6.50	2.76	-0.68	-0.54

4 RESULTS AND DISCUSSIONS

Table 2 shows the descriptive analysis carried out on all the items of the questionnaire. In general terms, the data show a good level of engagement with the BubbleMumble activity.

Specifically, students seemed to be interested in biology-related topics (Q1, avg=7.05, sd=2.25). This helped us to exclude potential bias in the students towards the topics covered by the Serious Game Bubble Mumble. Similarly, the response to question Q2 (avg=6.62, sd=2.62) highlights a possible difference in the way the introduction to the experimentation was conducted by the researchers prior to the start of the game activities. The low mean value (although positive), along with the two standard deviation points, highlight the need in the future to standardize this introduction so that it is the same regardless of the researchers conducting it and the classes in which it is carried out. Similarly, in order to achieve greater clarity in the instructions provided to students, it may be appropriate to revise the instructions given by the avatar during the Internship phase to make them more concise and clear.

The positive results of the responses to items Q5, Q6 and Q7 confirm the ideas that guided the design phase: the choice to create a mode in which the student could learn outside of the time-pressure typical of the Production mode turned out to be successful, and the players showed that they consider this mode useful for understanding and learning the concepts at the core of the nanoalgosome production process. The overall good response to items Q8 to Q13 also shows that students find the game useful for learning the biology-related content at the core of the dissemination aim. This is also confirmed by the positive values found for items Q16 and Q17. The greatest criticism is found in the responses to item Q20 and is addressed to the audio component of the game. Consequently, greater attention to elements such as soundtrack and audio effects (and potentially voice dubbing of instructions) could lead to an improvement in the overall perception of the game by students and thus increase its effectiveness.

A further positive point of this experimentation is the overall positivity of the responses found, es-

pecially in the classes of the first order secondary school, despite the fact that the game was only available in English, and not in the mother tongue of the students. In this regard, a localization in more languages could help to increase the effectiveness of the game and its distribution in more countries. It is also important to note that a more detailed analysis of the responses of the last classes (fifth year of high school) brought to the surface a decisively negative trend. These students found the game less engaging and useful and generally made more criticism of the graphical component. This unfortunately confirms the initial target design and discourages an expansion of the age range in which to use the game.

5 CONCLUSIONS AND FUTURE WORKS

This study represents a first step toward refining the game and how it is administered and used within the school setting. Many lessons can be taken from this experience. In regards to the levels of perceived engagement and boredom of the game, although the values detected are probably explained by the presence within the experiment of students with ages outside the design target group, it pushes to reason on how the game could be made even more engaging. Taking again inspiration from the Overcooked game, the introduction of multi-player modes (both direct, such as co-op play, and indirect, through the addition of elements such as leaderboards) could improve students' perception and actually increase the game's effectiveness. At the same time, the variance in the students' understanding of the tasks to be completed within the proposed activities defines the need to formalize an introduction that can be directly integrated within the game and that, consequently, does not require the intervention of an external person. Moreover, following the indications provided by the students' feedback, an improvement and, above all, greater attention in the design phase to the audio component of the game is necessary. Finally, while this experimentation was more useful to assess the level of enjoyment of the game and the activities carried out, it is important to plan and verify through a rigorous study the actual transfer of knowledge implemented by the game, to validate it as a tool for content acquisition.

REFERENCES

Adžić, S., Al-Mansour, J., Naqvi, H., and Stambolić, S. (2021). The impact of video games on students' educational outcomes. *Entertainment Computing*, 38:100412.

Ardley, G. (1967). The role of play in the philosophy of plato. *Philosophy*, 42(161):226–244.

Arnold, U., Söbke, H., and Reichelt, M. (2019). SimCity in infrastructure management education. *Education Sciences*, 9(3):209.

Bakhanova, E., Garcia, J. A., Raffe, W. L., and Voinov, A. (2020). Targeting social learning and engagement: What serious games and gamification can offer to participatory modeling. *Environmental Modelling & Software*, 134:104846.

Bereitschaft, B. (2021). Commercial city building games as pedagogical tools: what have we learned? *Journal of Geography in Higher Education*, pages 1–27.

Boyle, E. A., Hainey, T., Connolly, T. M., Gray, G., Earp, J., Ott, M., Lim, T., Ninaus, M., Ribeiro, C., and Pereira, J. (2016). An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games. *Computers & Education*, 94:178–192.

Charsky, D. (2010). From edutainment to serious games: A change in the use of game characteristics. 5(2):177–198.

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., and Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, 59(2):661–686.

de Freitas, S. I. (2006). Using games and simulations for supporting learning. 31(4):343–358.

ESA (2021). 2021 essential facts about the video game industry. https://www.theesa.com/resource/2021-essential-facts-about-the-video-game-industry. Accessed: 2022-02-22.

European Commission (2014). Communicating eu research and innovation guidance for project participants. https://ec.europa.eu/research/participants/data/ref/h2020/other/gm/h2020-guide-comm_en.pdf. Accessed: 2022-02-22.

Filsecker, M. and Hickey, D. T. (2014). A multilevel analysis of the effects of external rewards on elementary students' motivation, engagement and learning in an educational game. *Computers & Education*, 75:136–148.

Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., and Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in Human Behavior*, 54:170–179.

ISFE (2021). Key facts 2020 - european video games sector. https://www.isfe.eu/wp-content/uploads/2021/10/2021-ISFE-EGDF-Key-Facts-European-video-games-sector-FINAL.pdf. Accessed: 2022-02-22.

Kalogiannakis, M., Papadakis, S., and Zourmpakis, A.-I. (2021). Gamification in science education. a systematic review of the literature. *Education Sciences*, 11(1):22.

Karmakar, A., Bhushan, B., Santel, C., Sameer, A., and Bhattacharya, B. (2019). Interface design of low-

cost collision alerting system for sports aviation. In *Smart Innovation, Systems and Technologies*, pages 407–415. Springer Singapore.

Korteling, H. J. E., Helsdingen, A. S., and Sluimer, R. R. (2016). An empirical evaluation of transfer-of-training of two flight simulation games. *Simulation & Gaming*, 48(1):8–35.

Loganathan, P., Talib, C., Thoe, N., Aliyu, F., and Zawadski, R. (2019). Implementing technology infused gamification in science classroom: A systematic review and suggestions for future research. learn. *Sci. Math*, 14:60–73.

Mcgregor, G. (2021). China's gaming market was built on free and addictive games. can beijing stop kids from playing them? https://fortune.com/2021/09/03/china-video-gaming-mobile-smartphone-addiction-free-to-play. Accessed: 2022-02-22.

Mohammed, Z. and Khaled, F. (2021). A virtual method to estimate the aerodynamic coefficients of UAV. *Unmanned Systems*, pages 1–11.

Papastergiou, M. (2009). Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation. *Computers & Education*, 52(1):1–12.

Pramaputri, N. I. and Gamal, A. (2019). Urban planning simulation game and the development of spatial competence. *IOP Conference Series: Earth and Environmental Science*, 396(1):012016.

Roose, K. M. and Veinott, E. S. (2017). Roller coaster park manager by day problem solver by night. In *Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play*. ACM.

Sierra, J. (2019). The importance of simulation in teaching and learning economics: The students' perspective. *Innovations in Education and Teaching International*, 57(5):521–531.

Subhash, S. and Cudney, E. A. (2018). Gamified learning in higher education: A systematic review of the literature. *Computers in Human Behavior*, 87:192–206.

Zainuddin, Z., Chu, S. K.-W., Shujahat, M., and Perera, C. J. (2020). The impact of gamification on learning and instruction: A systematic review of empirical evidence. *Educational Research Review*.