On Effective Integration of Educational Content in Serious Games

Text vs. Game Mechanics

Andreea Molnar

Brunel University
United Kingdom
Andreea.Molnar@brunel.ac.uk

Patty Kostkova

University College London
United Kingdom
P.Kostkova@cs.ucl.ac.uk

Abstract—**As serious games are emerging as a new educational paradigm, it is increasingly important to understand how to integrate educational content into the games, and what elements of the game make learning more effective. This research proposes to add to the work in the area by examining whether learning objectives delivered through the game narratives as text, or learning objectives delivered through game mechanics provide more effective way of integrating educational content in a game. In order to investigate this question, we designed a study evaluate two types he participants who were divided into two groups to take part in complementary version of the game. Participants are asked to play a game in which learning objectives are delivered either through text or game mechanics. An evaluation was performed with 60 participants. The results show that for one of the learning objectives, the participants learn more when the educational content was integrated through the game mechanics and that the difference between the groups who learn through text and the one who learned through game mechanics is statistically significant. For the rest of the learning objectives covered no statistically significant difference was obtained between the two ways of integrating the learning objectives.**

Keywords- health; entertainment; serious games; narratives; game mechanics; game design; ludology

I. INTRODUCTION

Educational games are emerging as a new educational medium. However, the research literature reports mixed results with regards to game effectiveness in delivering educational content [1]. Most often, they note the lack of empirical evidence on what and how the elements of the game affect Learning Objectives (LO) assimilation [2] and "almost no guidance for game designers and developers on how to design games that facilitate learning" [3].

This paper adds to the state of art in this area by examining what is more effective at delivering educational content: integrating it through the text, or through the game mechanics. Game mechanics are essentially present in every game genre, whereas narratives can be a predominant part in some genres such as storytelling games, but they can be completely missing in others. By game mechanics in this paper we understand "the procedural mechanism of a game that provides the essential interactions required to create a meaningful game activity" [4]. The educational content is

intrinsically integrated [5] in the game regardless of the method through which it is delivered: text or game mechanics. The text is seamlessly integrated in the game narratives and the game mechanics through which the educational content is delivered is connected with the other mechanics of the game and with the narratives.

Text is a simple way of conveying educational messages that can be delivered easily through traditional game design opportunities (mission briefings, in-game conversations etc). However, teaching through game mechanics requires that the player interprets game dynamics correctly and discovers and constructs the educational message with less clear directions. The appeal of this approach lies in understanding constructivist learning theories, where individuals must construct their own knowledge, rather than simply being 'told' new things. However, there is a risk that the player does not understand or interprets the game's mechanics correctly. There is also the fear that the student might fail to construct the "hidden curriculum" [6, 7] some studies showing that the transfer between the game context to another context (i.e. classroom)does not always happens [1]. On the other side, game mechanics could provide a better learning experience than text and better engage the player with the content. In this context, we are investigating how LOs have to be delivered in order to be the most effective in educational games: through text or game mechanics.

The rest of this paper is organized as follows. The next section presents previous work in educational game design. Afterwards the study design is presented followed by the evaluation results. The last section ends the paper with our conclusions and future work.

II. BACKGROUND WORK

Designing educational games so that they are not only entertaining but also effective in delivering educational content is an area that requires further explorations [1, 2]. Different studies have been looking at how the games have to be designed in order to make them more effective [4, 8-13].

[12] suggests a framework based on challenge, fantasy and curiosity for an intrinsically motivated instruction in games. The framework is intended as a "checklist of heuristics that will be used in designing the instructional environment". The study concluded that the effectiveness of the game in delivering educational content depend on the way fantasy is integrated in the game context. A more recent

study [4] argues that it is that to intrinsically integrate the educational content in game the game mechanics and not fantasy are the critical elements.

Other studies have looked at how different features of the game affect learning [10], or how the educational content is to be integrated seamlessly into the game narratives [13]. [10] proposes to add speech recognition support to two mobile learning games with the aim of improving literacy skills. Their results show that speech recognition helps at improving the extraction but not the decoding skills.

[11] looks at what aspects of the game are contributing to learning. They assessed how game reality, conflict, challenge, and assessment affect the learning outcome. The study concluded that the most effective games are endogenous, adaptive and both in process and completion feedback should be given to the player. Although our game integrates these aspects, we do not look into them in this research, we are researching the way the educational content is delivered: either through text, game mechanics, or both.

[8] looks at whether or not adding narratives to adventure computer games improves the academic learning content and the learner enjoyment. They find that the addition of narratives does not significantly enhance the learning of educational content. When looking at the learner enjoyment, participants who played the game enhanced with narratives enjoyed the game slightly more, but this difference was not statistically significant.

Although the research of [8] shows that narratives do not add value to games, our approach is differentiated from the one presented in this paper by the fact that we include the educational content in the narrative as a text, whereas in the study performed by [8], the narratives are added just as a support to the game, and the educational content was not actually integrated into the narrative. Their approach has been shown not to be suitable for educational games as the players pay more attention to the story and ignore the educational content that is being taught [14].

Therefore, we differentiate from the above research by looking at two methods in which LOs could be integrated into the educational game: through game mechanics or text.

III. STUDY DESIGN

A. Game Description

For our evaluation, we use level two and level three of the Bugs Kingdom [15] game. Bugs Kingdom is a curriculum-based game, designed to teach young people about microbes, hygiene and proper antibiotic use. A group of experts in the area helped at selecting the suitable LOs based on the European curriculum, and advising at designing the microorganism in the game to be as similar as possible to reality, but still pleasant for children. The game was also iteratively evaluated at different stages during the implementation. For example, focus groups were done with students to determine the preferred game genre for our considered age group [17].

Bugs Kingdom uses bespoke game mechanics to teach LOs. For example, to teach "microbes are used to make

yogurt" the player has to push lactobacillus bacteria into a glass of milk, which as a result turns into yogurt (Fig. 1).

Figure 1.   Game mechanics in Bugs Kingdom: pushing lactobacillus bacteria into a glass of milk

The LOs are reinforced in the game in two ways: either the player had to re-apply the game mechanics teaching a LO in a different context or through explicitly conveying the LO through text (Fig. 2).
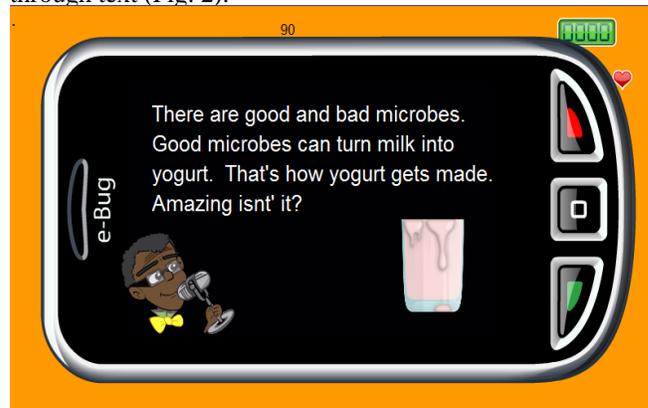

Figure 2.   LOs delivered through text in Bugs Kingdom

To assess the participants' knowledge about the LOs that are taught in the game, a pre and post questionnaire was integrated as a separate game at the beginning and at the end of each level. The game was designed to be similar to "How to be a Millionaire" – called here e-Bug Game Show. During this game, a facilitator asks questions and the player has to provide answers competing against a virtual character (see Fig. 3). When providing answers, the player has to choose among one of the three options regarding the sentence representing the LO: "Agree", "Disagree" or "Don't know" (see Fig. 4).

For evaluation purposes only we learned through the actual game and not through the evaluation game, no feedback is provided in the first round, called "Blind Question Round", because this round is provided before the actual game play took place. However, feedback in the form of whether the questions are right or wrong is provided during the second round, which is performed at the end of the game level.

Figure 3. The integrated game through which the player knowledge about the LOs presented in Bugs Kingdom is evaluated
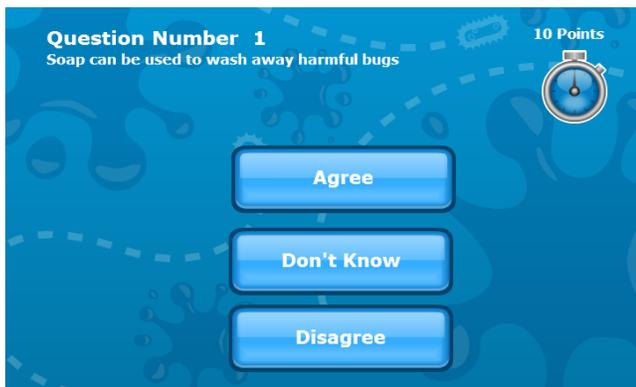

Figure 4. Answer options provided to the playersfor knowledge evaluation

Bugs Kingdom has five different levels [16]:

- *Introduction to Microbes*: aims to familiarise the player with different types of microbes.
- *Harmful Microbes*: presents the player with microbes that are "harmful" for humans and it shows how the player can "fight" them.
- *Useful Microbes*: teaches players that there are also good microbes and what their usefulness is.
- *Hygiene*: teaches the player about food hygiene.
- *Antibiotics*: reinforces responsible antibiotic use.

Since playing the full game takes a long time, and from previous evaluations we have observed that players drop out before reaching the last level [17], we decided to select for this study just two levels of the game: level two (*Harmful Microbes*) and level three (*Useful Microbes*). We selected these two levels as they easily allow teaching the LOs through one of the modalities (either text or game mechanics). Moreover, the levels taught similar LOs and have similar game mechanics. On top of that for two of the LOs statistically significant players' knowledge improvement was obtained when the game was evaluated, and the other two were not statistically significant. This was done to have a mix of LOs, not only the ones who are taught better or worse by the game. For more details of the evaluation please see

B. Learning Objectives

The four LOs that are taught by Harmful Microbes and Useful Microbes as standalone either through text or game mechanics are:

- LO 1: Soap can be used to wash away bad bugs
- LO 2: Our bodies have natural defences that protect us
- LO 3: All microbes are bad for us
- LO 4: We use good microbes to make things like yogurt

The first two LOs of the games are taught in *Harmful Microbes*, whereas the last two in *Useful Microbes*.

C. Game Mechanics Designed to Teach LOs

Each of the above LOs can be taught through game mechanics. In each case, during the game, the player is shrunk to the size of the microorganism and s/he has to perform different tasks in different game locations (e.g. on the human hand, inside the human body etc). A portal transfers the players to different locations of the game if the player manages to pass the probes in the game. The game mechanics used to teach each of the LOs are explained below:

Soap can be used to wash away bad bugs: - The player is on the human hand. Here, he has to collect soap and throw bubble soap at the harmful microorganism that he finds on his way towards the portal (Fig.5). When the soap bubbles touch a microorganism, it disappears. If the player touches one microorganism before the microorganism is touched by a soap bubble, he loses one "life" from the three s/he has in total.
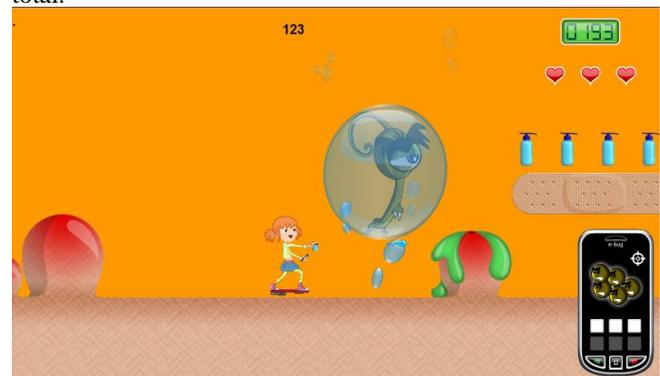

Figure 5. Game mechanics: Soap can be used to wash away bad bugs

Our bodies have natural defences that protect us: - The player is shrunk and transported inside the human body. S/he has to collect white blood cells and throw them at the microbes s/he finds in his way (Fig. 6). In a similar way as before, if the player touches one micro before it is "killed" by the white blood cell, the player loses one of his/hers three lives.

Figure 6. Game mechanics: Our bodies have natural defences that protect us

We use good microbes to make things like yogurt: - The player is in the kitchen. Here s/he has to push lactobacillus bacteria into a glass of milk (Fig. 1). When the bacterium touches the milk the milk becomes yogurt (Fig. 7).

Figure 7. Game mechanics: We use good microbes to make things like yogurt & All microbes are bad for us

All microbes are bad for us: - The player has to deduce from the previous game mechanics that actually not all the microbes are good, and some can be used to make things.

IV. EVALUATION

The aim of the evaluation is to determine which of the two ways of delivering the LOs: through text or game mechanics is more effective in teaching the player the LOs. With this aim, *Harmful Microbes* and *Useful Microbes*, level 2 and level 3 of the Bugs Kingdom game have been modified so that they are independent games. In each level, all of the LOs were taught only through text and the other two through game mechanics only in each game.

To evaluate our hypothesis, *Harmful Microbes* was changed so that the last two LOs from Table 1 (LO 3 and LO 4) are taught through text while the first two (LO 1 and LO 2) are taught only through game mechanics. The text that teaches the LOs is integrated in the game, and is presented at the beginning to the player, in the same part of the game where the instructions for the game are presented. The player cannot skip this part or the game mechanics if s/he finishes

the game. The narrative bit is presented at the beginning of the level, whereas the game mechanics afterwards.

To evaluate our hypothesis, *Useful Microbes* was changed in a similar way. The first two LOs (LO 1 and LO 2) are taught through text and the last two LOs (LO 3 and LO 4) are taught only through game mechanics. As in the previous case, the text teaching the LOs is integrated with the game narratives and is presented at the beginning.

In both games, the players cannot skip any of the parts teaching the LOs, whether they are presented through text or through the game mechanics as they are both mandatory parts for the player in order to finish the game.

A. Demographics

The participants were asked to play one of the versions of the game. They were 6 to 11 year olds, and were asked to play on a volunteer basis. 30 children play Harmful Microbes modified as a game and 30 played the modified version of the Useful Microbes. The evaluation took place at the V&A Childhood Museum and St Mary's Community Centre, London, UK.

B. Pre-Test

To determine whether the two groups of participants have the same knowledge when they started the game, regardless of the LOs taught in the game, a t-test [18] was performed between the answers given by the participants in the two groups for each of the LOs covered in the game. A confidence interval of 95% was considered for statistical significance. The results show that there is no statistically significant difference in terms of pre-knowledge between the two groups, regardless of the LOs. The p-value for each of the LOs are:

- 0.67 for LO 1
- 0.26 for LO 2
- 0.15 for LO 3
- 0.14 for LO 4

Since the two groups do not vary significantly in their knowledge, only the post-test results will be used further on in the analysis.

C. Post-Test

After the game playing session, the participants' knowledge is evaluated again. The aim is to determine whether there is any difference in students' knowledge when they were taught a LO through text or through game mechanics. A t-test was performed on the participants answers when they were taught a LO through text and through game mechanics. A confidence interval of 95% was considered for statistical significance. The results showed that apart for one LO, the results were not statistically significant. The p-value for each of the LOs are:

- 0.09 for LO 1
- 0.17 for LO 2
- 0.05 for LO 3
- 0.11 for LO 4

The LO for which statistical significance difference in post-test results was obtained between those that were taught through text or those that were taught through game

mechanics is the LO 3: *We use good microbes to make things like yogurt.* For this LO the players that were taught through game mechanics obtain better post-test results than the one who were taught through text.

V. CONCLUSIONS AND FUTURE WORK

This research is aimed at assessing whether delivering the LOs through text or game mechanics produces better knowledge gain results when both methods of delivering the LOs are integrated into the game. The results show that for one of the LOs evaluated, having it integrated through game mechanics produced better results than the when it was integrated trough text and the difference in players results are statistically significant. For the rest of the LOs there is no statistically significant difference in how much the participants learned between the two groups.

A future research direction will be to try to replicate the results with multiple LOs across different game types. Moreover, we want to assess how the way the LOs is integrated in the educational game affects the player knowledge over a longer period of time. We are planning to expand our work and take into consideration how other variables can impact the results, such as students characteristics, gameplay duration.

ACKNOWLEDGMENT

REFERENCES

[1] D. Bavelier, C. S., Green, D. H., Han, P. F., Renshaw, M. M.., Merzenich, and A. A. Gentile, "Brains on video games," Nat. Rev. Neurosci., vol. 12, pp. 763-768, 2011.

[2] K. A. Wilson, W. L., Bedwell, E. H. Lazzara, E. Salas, C.S. Burke, J. L. Estock, K. L. Orvis, and C. Conkey, "Relationships between game attributes and learning outcomes: Review and research proposals", Simulation Gaming, vol. 40, no. 2, pp. 217-266, 2009.

[3] H. F. O'Neil, and R. S. Perez, "Computer games and team and individual learning," Amsterdam, Elsevier, 2008.

[4] M. P. J. Habgood, and S. E. Ainsworth, "Motivating children to learn effectively: exploring the value of intrinsic integration in educational games." The Journal of the Learning Sciences, vol. 20, no. 2, pp. 169-206, 2011.

[5] Y. B. Kafai, "Learning design by making games." Constructionism in practice: Designing, thinking and learning in a digital world, pp. 71-96, 1996.

[6] P. Starr, "Seductions of Sim: Policy as a Simulation Game," The American Prospect no. 17, pp. 19-29, 1994.

[7] S. Turkle, "From powerful ideas to PowerPoint." Convergence: The International Journal of Research into New Media Technologies vol. 9, no. 2, pp.19-25, 2003.

[8] D. M. Adams, R. E., Mayer, A., MacNamara, A, Koenig, and R. Wainess, "Narrative games for learning: testing the discovery and narrative hypotheses," J. of Educational Psychology, vol. 104, no. 1, pp. 235-249, 2012.

[9] M. Chmiel, "Game design towards scientific literacy," Cognitive Technology Journal., vol. 14, no. 2, pp. 5-15, 2010.

[10] A. Kumar, P. Reddy, A. Tewari, R. Agrawal, and M. Kam, "Improving literacy in developing countries using speech recognition-supported games on mobile devices," In Proc. CHI 2012. ACM Press pp. 1149-1158, 2012.

[11] D. Pavlas, W. Bedwell, S. R. Wooten, K. Heyne, E. Salas, "Investigating the attributes in serious games that contribute to learning", Human Factors and Ergonomics Society Annual Meeting, vol. 53, no. 27, pp. 1999-2003, 2009.

[12] T. W. Malone, "Toward a theory of intrinsically motivating instruction." Cognitive science, vol. 5, no.4, pp. 333-369, 1981.

[13] A. Molnar, D. Farrell, and P. Kostova, "Who poisoned hugh?-the STAR framework: integrating learning objectives with storytelling." Interactive Storytelling , pp. 60-71, 2012.

[14] M. B. W. Wolfe, and J. A. Mienko, "Learning and memory of factual content from narrative and expository text," British Journal of Educational Psychology, vol. 77, pp. 541–564, 2007.

[15] Bugs Kingdom. http://www.edugames4all.org/IntegratedCRD.nsf/a2e0dec55e90eaac80257914005ad890/94e51e8758fdf2e080257914005cf42d?OpenDocument

[16] D. Farrell, et al. "Developing eBug games to teach microbiology," J. Antimicrob. Chemother, vol. 66, pp. 33-38, 2011.

[17] D. Farrell, et al. "Computer games to teach hygiene: an evaluation of the e-Bug junior game," J. Antimicrob. Chemother, vol. 66, pp. 39-44, 2011.

[18] H. Hsu, and P.A. Lachenbruch, Paired t Test. Wiley Encyclopedia of Clinical Trials, 2008.