

Computer games to teach hygiene: an evaluation of the e-Bug junior game

David Farrell¹, Patty Kostkova^{1*}, Julius Weinberg¹, Lisa Lazareck¹, Dasun Weerasinghe¹, Donna M. Lecky²
and Clodna A. M. McNulty²

¹City eHealth Research Centre (CeRC), School of Community and Health Sciences (SC&HS), City University London, Northampton Square, London EC1V 0HB, UK; ²Health Protection Agency, Primary Care Unit, Microbiology Department, Gloucestershire Royal Hospital, Great Western Road, Gloucester GL1 3NN, UK

*Corresponding author. Tel: +44-207-040-4084; Fax: +44-207-040-8795; E-mail: patty@soi.city.ac.uk

Handwashing, respiratory hygiene and antibiotic resistance remain major public health concerns. In order to facilitate an effective outcome when teaching the basic principles of hand and respiratory hygiene, educational interventions should first target school children. As computer games are ubiquitous in most children's lives, e-Bug developed computer games targeted at teaching children handwashing, respiratory hygiene and antibiotic resistance. The games were designed for two target audiences: junior school children (9–12 year olds); and senior school children (13–15 year olds). Between May and August 2009, the finalized junior game underwent an evaluation in three UK schools (in Glasgow, Gloucester and London), involving 62 children in the schools and ~1700 players accessing the junior game online. The e-Bug junior game consists of a number of levels of play, each of which promotes a set of learning outcomes (LOs). These LOs, complementary to those in the e-Bug packs, are expressed through the game mechanics (the rules of the game) rather than through story or dialogue. Although the junior game's evaluation demonstrated a statistically significant change in the knowledge for only a small number of given LOs, because many children had the required knowledge already before playing the game, this is e-Bug's first statistical study on the junior game and the first comprehensive evaluation of its kind. Future work includes a re-examination of the quiz-style questionnaires utilized in this study and an exploration of the potential knowledge change acquired strictly through engagement.

Keywords: antibiotic resistance, microbiology educational tools

Introduction

Handwashing, respiratory hygiene and antibiotic resistance remain major public health concerns at the European level. In order to ensure increased knowledge in these topics, educational interventions need to first address children. Therefore, the e-Bug Project developed computer games piloting this new and popular medium to teach children an agreed set of learning outcomes (LOs). The games were developed to complement the information and style of the e-Bug pack, with links to each partner country's curriculum. The games were designed for two target audiences: junior school children (9–12 year olds); and senior school children (13–15 year olds). Through the European partnerships, it became clear that the information technology provision in most European schools does not allow the use of in-class computer games; therefore, the games were developed and evaluated as standalone entities to be used alongside or independently of the e-Bug pack.

Computer games are part of most children's lives in the developed world.^{1,2} Playing computer games provides a learning experience, whether the player is a novice or expert, or merely

learns the rules of the game and improves playing performance. Gee³ stated that the commercial success of a game (and its designer) rests upon the ability of the player to improve and finally master it: 'Thus, designers face and largely solve an intriguing educational dilemma, one also faced by schools and workplaces: how to get people, often young people, to learn and master something that is long and challenging—and enjoy it, to boot.' Games require problem solving, but may also call upon social and collaborative skills.⁴

The popularity and motivational power of games, as well as the opportunity to harness the learning that happens in games, has led to an interest in the development of games for education.⁵ However, this is a very recent phenomenon and the success of the educational impact of games still needs examination and comprehensive analysis. Computers have become ubiquitous in the classroom and the educational software industry has grown enormously in the past 20 years. Recent research carried out by FutureLab for BECTA (the government agency leading the UK drive to ensure the effective and innovative use of technology through learning) reported that of the UK teachers sampled, 35% had already used computer

games for teaching purposes and 60% would consider using them in future.⁶ The report also suggested that the use of games improved children's motivation and engagement, but it was not clear that the games themselves enhanced the attainment of LOs. The results of much 'edutainment' (or educational entertainment) have been disappointing. For example, in 1993, Brody⁷ criticized the production of not very entertaining games with poor educational material. Ten years later, Kirriemuir and McFarlane⁵ further suggested that educational games continue to fail when competing with commercial games, due to the former's simplistic, repetitive and poor design. In 2007, Wideman et al.⁴ stated that 'Significant bodies of research in educational gaming exist in only two disciplines—medical education and business management studies.' In this study, Wideman et al. did not fully define their use of the term 'significant'. They also noted the paucity of well-designed game evaluations and the limited (and anecdotal) evidence supporting the use of computer games for education. In contrast, Egenfeldt-Nielsen^{8,9} concluded that the findings reported in >300 articles on obtaining LOs through the use of computer games in education (published between 1984 and 2005) were positive and promising. Scientific game evaluations were identified in 24 articles, of which 13 described a learning benefit achieved in health education or programming education. (Unfortunately, the author did not describe their literature review method nor did they explain the inclusion/exclusion criteria by which the articles were chosen.) For many of the studies reviewed, Egenfeldt-Nielsen^{8,9} noted poorly described and constructed evaluation methodologies, the lack of a control group, as well as researcher bias and poor assessment tests.

In this paper, we present a study evaluating the junior game developed for e-Bug. The game consists of a number of levels, each of which teaches a set of LOs. The player chooses an avatar that is shrunk enough to fit inside the human body, and she/he interacts with useful and harmful cartoon microbes in various contexts and scenarios. The LOs are taught through the game's mechanics (the rules of the game) rather than through its story or dialogue. For example, instead of telling the player that soap washes harmful microbes off the skin, the player is told to throw globules of soap at microbes, whereby the harmful microbes are made to disappear in real-time, i.e. as the child plays. The junior game was designed to incorporate aspects of popular games for the target audience (9–12 year olds)—including platform game mechanics (e.g. the *Super Mario Brothers* series from Nintendo), reaction 'twitch' game mechanics (e.g. *Whack-a-Mole*) and quiz games (e.g. *Who Wants to be a Millionaire?*). For the purpose of this study, a successful outcome for the junior game evaluation was defined as the acquisition of knowledge of set e-Bug LOs through game play.

Methods

The e-Bug games were developed to teach the e-Bug set of LOs, which were defined by the e-Bug partners in year one of the 3 year project. The overview description of the games is available in Kostkova et al.¹⁰ Throughout the development of the game, focus groups and observational studies at primary schools were performed and evaluated, in order to aid game focus and improvement.¹¹ In this article, the examined game evaluation took place between May and August of 2009, in three

UK schools (in Glasgow, Gloucester and London). In order to avoid bias in our results for gain in knowledge, the 62 participating children did not include any student who contributed to our pilot evaluation or focus group-based evaluation of the usability of the junior game. In addition, several schools and school-related contacts were e-mailed to advertise the e-Bug junior game and request that interested children visit the e-Bug web site to play the game online. Overall, 1674 participants responded and played the games—with their results included in our subsequent analysis. The children who played the junior game in-school were given a set amount of time by their teacher, within the range of 20–60 min. The online participants had no set time constraint. On average, the junior game takes 30–40 min to play.

In this study a knowledge-gain test was developed, by adapting the e-Bug pack evaluation test, to assess the educational impact of each of the five levels of the junior game. In order to test children's increase in knowledge, a 'game show' quiz was incorporated into the game structure, i.e. a series of tailored knowledge-assessing questions (for specific LOs that were based on the e-Bug developed pack). For example, before Level 1, the player was asked a series of questions before proceeding to play that level. Upon successful completion of the level, the player was then asked the identical (pre-game) questions and was then told if their answers were correct. The structure of the junior game is illustrated in Figure 1. For evaluation purposes only, the pre-game questions are referred to as the 'blind round'. In the final version of the junior game, currently available online, the 'blind round' has been removed. Thus, with identical pre- and post-game questionnaires, we are able to evaluate the knowledge gain, if any, of the LOs. The three available user responses to the questions included 'yes', 'no' or 'don't know'.

Both the in-school and online participants played the junior game over the Internet. A tally was recorded of the number of participants who completed each level. At the end of each completed level, the player's pre- and post-level answers were stored in an IBM Lotus Notes database, used for the development of the e-Bug site and exported for evaluation into Microsoft® Office Excel®, where the data were analysed using a set of functions developed for the purpose of this analysis.

Data analysis

Players could give a correct answer (C), a wrong answer (W) or a 'don't know' answer (?). For example—and also utilizing logic symbols '!' for 'or' and '&' for 'and'—referring to Table 2: '(W|?)&C' means that pre-level the player answered either incorrectly or selected the 'don't know' response and post-level answered correctly; and 'C&(W|?)' means that pre-level the player answered correctly and post-level either answered incorrectly or selected the 'don't know' response. The success of the knowledge change (of the LOs) and the statistical significance was calculated using McNemar's test, which is used to assess paired data, applied to individuals with a change in response from wrong or 'don't know' to correct, or vice versa; i.e. '(W|?)&C' and 'C&(W|?)'. The resultant χ^2 value and the *P* value for significance were computed, and are illustrated in Table 2.

Results

Table 1 describes the number of users remaining after each completed level of the junior game. Roughly 50% of the players who started the game dropped out before completing the first level. Similarly, after each subsequent level, ~50% of the remaining players did not complete the level and closed the game. Therefore, there is a large difference between the numbers of players exposed at each level: 652 players completed Level 1, but only 54 players completed Level 5. Further investigation is required to understand the drop in player numbers after each

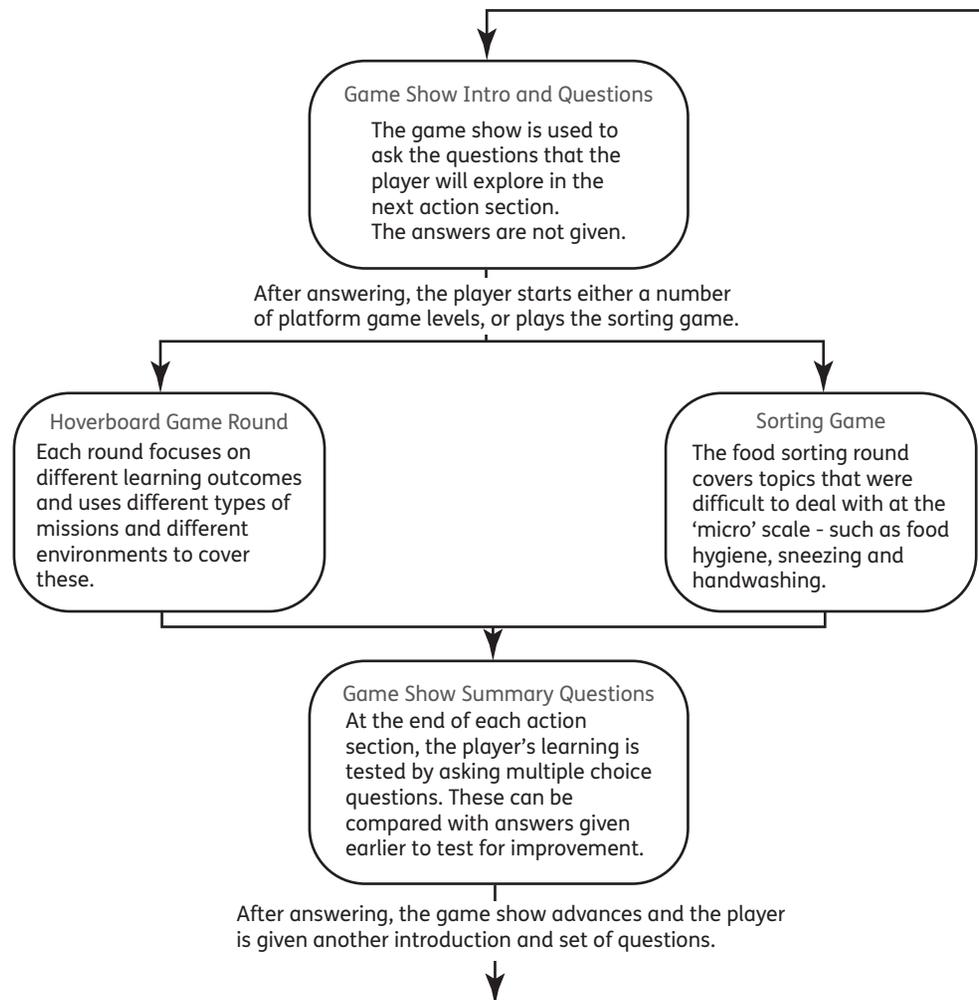


Figure 1. The players were given pre- and post-level questionnaires at each game level for assessment purposes.

Table 1. The number of players remaining at each level

Level attained	Number of players
Started the game (62 in-school plus 1674 online)	1736
Completed Level 1: Introduction to Microbes	652
Completed Level 2: Harmful Microbes	317
Completed Level 3: Useful Microbes	181
Completed Level 4: Hygiene	81
Completed Level 5: Antibiotics	54

game level. There are several hypotheses, including: the levels were too easy or too difficult; the levels took too long to complete; or the participants were bored with the game. Alternatively, the participants could have had very limited game-playing time and had to close their Internet browser.

For subsequent analysis, it was necessary to clean the above data, such that only child participants would be included. For example, of the 1736 players who started the game (62 in-school plus 1674 online), 36 players were

removed, including the game developer and other teachers and healthcare professionals associated with the project who played the game during the aforementioned time period. However, as many players did not provide this optional demographic information, the data could not be cleaned completely. Table 2 shows the number of players remaining after the data were ‘cleaned’. For example, after Level 1 was completed, 623 (of 652) players remained for analysis. Note that it was only possible to record the number of players to complete each entire level and not at each specific question in the quiz round per level.

Overall, the majority of players did not change their knowledge as a result of the game. There was no clear trend or pattern, for all five game levels, regarding the significance of the knowledge change gained by the players—apart from the following three notable exceptions. The questions with the most significant knowledge change stem from Level 3, Question 1: *We use good microbes to make things like bread and yogurt* ($P < 0.001$, $\chi^2 = 14.46$) and then Level 1, Question 1: *If you cannot see a microbe it is not there* ($P = 0.02$, $\chi^2 = 5.60$). Also, similar results were gained in Level 2, Question 2: *Soap can be used to wash away bad bugs* ($P = 0.02$, $\chi^2 = 5.28$).

Table 2. Summary of player responses for questionnaires for each game level, including the specific questions provided at each level corresponding to e-Bug pack learning outcomes

Level	Question	Players remaining	Pre and post responses ^a				Subtotal of interest	Subtotal of remaining	McNemar χ^2	P value
			C&C	W&W	(W ?)&C	C&(W ?)				
1	If you cannot see a microbe it is not there	623	469	58	48	27	602	21	5.60	0.02
	Bacteria and viruses are the same		379	84	64	46	573	50	2.78	0.10
	Fungi are microbes		311	114	68	60	553	70	0.56	0.45
	Microbes are found on our hands		460	63	45	36	604	19	0.89	0.34
2	All bacteria are harmful	304	221	26	19	22	288	16	0.15	0.70
	Soap can be used to wash away bad bugs		216	22	38	20	296	8	5.28	0.02
	Most coughs and colds get better without medicine		125	84	40	29	278	26	1.60	0.21
	Our bodies have natural defences that protect us against infection		205	27	29	26	287	17	0.11	0.74
3	We use good microbes to make things like bread and yogurt	176	123	14	29	6	172	4	14.46	<0.001
	All microbes are bad for us		134	9	15	8	166	10	1.84	0.18
4	Raw meat should go on the top shelf of the fridge	75	25	21	11	9	66	9	0.11	0.74
	Milk and other liquids should be in the fridge door		56	4	9	5	74	1	0.88	0.35
	It is safe to put opened tins in the fridge		25	17	14	10	66	9	0.51	0.47
	You should wash your hands after handling raw meat		59	3	10	3	75	0	3.25	0.07
	If you sneeze, you should wash your hands before handling food		62	3	7	3	75	0	1.23	0.27
5	Antibiotics kill bacteria	52	27	5	12	8	52	0	0.61	0.43
	Antibiotics kill viruses		15	16	7	8	46	6	0.15	0.70
	Antibiotics will cure any illness		34	6	7	3	50	2	1.23	0.27
	Antibiotics can harm our good bacteria as well as bad bacteria		25	8	12	4	49	3	3.52	0.06
	Antibiotics help when you have a cough		12	18	6	8	44	8	0.45	0.50
	Most coughs and colds get better without antibiotics		30	10	3	6	49	3	1.36	0.24

^aThe pre and post responses are written via symbols between the '&' where C=correct, W=wrong and ?='don't know'. For example, 'C&C'=correct pre-level and correct post-level answers; 'C&(W|?)'=correct pre-level answer and either wrong post-level answer or 'don't know' response selected. 'Subtotal of remaining' refers to the tallied players' responses for the following cases: '?&?', '?&W' and 'W&?'—or a subtraction of 'Players remaining' and 'Subtotal of interest'.

Discussion

The most successful games-based learning mechanic involved the pushing of 'Lucy Lactobacillus' into a glass of milk to make yogurt (Level 3, Question 1). This was followed by 'shrinking' the player to a size small enough to enter the body or sit on the skin, to give an insight into the size and invisibility of microbes by the human eye (Level 1, Question 1). Lastly, the exercise to wash bad bugs away by throwing water bubbles and using soap dispensers, and, in turn, watching the animation show the microbe disappear in the bubble (Level 2, Question 2) seemed clearly to convey the learning objective. These LOs may have been more successful as they were very obvious; visually obvious to the participants, that is, whereas other questions rely on the player utilizing what they see/do and contextualizing it in terms of the questions asked. For example, 'Microbes are found on our hands' relies on the player making the connection that since their shrunken avatar was taking photographs of microbes whilst on the skin of a hand, microbes are therefore found on the hand.

This study on the quantitative evaluation of LOs using the e-Bug junior game is one of the largest studies of its type

reported. There are few examples in the literature that describe how predefined LOs are both incorporated into game mechanics and evaluated from subsequent game-playing; therefore, the e-Bug junior game is, as far as we are aware, the first publication of a research experiment demonstrating a statistically significant user knowledge change against predefined LOs. Also, this study presented the material under 'real world conditions'; i.e. over the Internet rather than in a controlled classroom or under experimental conditions, as has been reported in previous game evaluation studies.¹²

After analysing the results of 1700 game-playing participants, we have found that in only 3 out of 21 questions (based on LOs) did the players experience a statistically significant knowledge change ($P \leq 0.02$). A greater improvement of knowledge was expected from this pilot quantitative study; however, the majority of players knew the correct answers before starting the game. From a public health point of view, this is a positive outcome; for all five levels, ~50% or more of the players correctly answered the pre- and post-game questions. There is a likely correlation of the responses across questions and also across levels as the player proceeds through the game. The next study

following this pilot project would benefit from a modelling approach to incorporate these factors.

In addition, the small number of players in Levels 4 and 5, caused by a rather high dropout rate, also contributed to the fact that there was no statistically significant knowledge gain in these last two levels. It was not possible to determine whether the children participating in the evaluation of the game had already covered these topics in their science lessons at school or whether they were taught from the e-Bug pack, as this information was not collected. It is important to note a common bias in measuring knowledge gain, as it could be argued that players learned more about game playing instead of the LOs. It is also possible that even though participants did not score well, they may have enjoyed the 'edutainment' and improved their understanding of the LOs through playing the game, but then did not cognitively participate in answering the questions and clicked through the questions so as to return to the game for playing. We think this may have occurred, as in our focus group's qualitative evaluation, the game show questionnaires were reported to decrease user experience, playability and usability of the game. Furthermore, an in-depth analysis is required to ascertain why the drop-off rates were so high such that very few participants reached these latter Levels 4 and 5. In future, the junior game will be split into individual levels and evaluated accordingly.

Learning is an activity with multiple outputs, not merely the retention of facts.¹³ In the constructivist philosophy of education, knowledge change is learning. Knowledge change can, however, also transpire without being revealed in tangible changes, such as exam results or pre/post questionnaires. A person, such as our game player, may be able to develop an increased understanding of the underlying LOs without having indicated this learning via a questionnaire. Further views on this method of knowledge change suggest that engagement in the learning process helps build on past experiences, deconstruct old meanings, construct new meanings and, hence, contributes to learning.¹⁴ Therefore, future work for the evaluation of the junior game includes further assessment of the engagement of the player and their attitude towards the game itself (education or entertainment?), in addition to the knowledge change hypothesis provided above. Finally, the ultimate aim of e-Bug is to facilitate a behaviour change through, or even without, knowledge acquisition. A resource-demanding behaviour study was, however, beyond the scope and means of this project, and will be the subject of future work.

Conclusions

This evaluation of the online e-Bug junior game, which teaches 9–12-year-old children the basic principles of hand and respiratory hygiene and antibiotic resistance, demonstrated statistically significant effectiveness of knowledge change for some of the given LOs. More work is required to ascertain the game players' attitude towards the e-Bug game itself and how much learning can be achieved through the act of game playing itself or game engagement.

Implications

The quantitative junior-game evaluation took place independently of the e-Bug pack evaluation. The effectiveness of teaching the LOs may be improved by integrating the junior game into

the main teaching process, rather than as a standalone activity. Because of the high number of correct pre-/post-game responses to the questions, a larger number of participants may be required to reach statistical significance in the knowledge-change goal of this study. Alternatively, the LOs (and incorporated junior game questions) may require modification due to the apparent very good basic knowledge of children (the target demographic) today.

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