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Taming the devil: A game-based approach to teaching immunology

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Immunology is a complex field requiring rapid memorisation of numerous components. An in-depth understanding of cellular and molecular biology is required before even moderately advanced concepts can be taught. We sought methods that actively engage students and help develop new knowledge and consolidate existing concepts to support lectures. We created an interactive and entertaining prototype immunology computer game as a tool for learning and revision, with the ability to interactively cover course content outside of class that modern learners expect. Our prototype appears to be a successful study aid when used additionally to attendance at lectures. We seek to continue the development of the game in a higher education context, but also produce a modified version for a secondary school context, in an effort to raise the profile of this key health area and promote learning for the future through the study of the sciences prior to students entering higher education.

Keywords: immunology, computer game, educational gaming, serious gaming

Introduction

Computer games have made a significant cultural, social, economic, political, and technological impact on society and are no longer used simply to entertain (Newman, 2004; Kapp, 2012). Computer game-based learning strategies are a useful tool in primary, secondary and tertiary-level education (Begg & Dewhurst, 2005). In 2001, the Federation of American Scientists (FAS) began gathering research about how technology could be used to transform education. Such technology is useful in complex, high content curricula that are difficult to grasp for a variety of legitimate reasons (FAS 2009). Effective learning and teaching systems that engage next-generation scientists often include an element of computer gaming. Such systems include pedagogy and instructional design, building physically correct interactive simulations, dialogue and question management, learner modeling, and tools for assembling and constructing learning systems from these components. The current literature indicates that learning through game-based approaches results in higher rates of knowledge retention and comprehension as opposed to the traditional paper-based pedagogues (Ke, 2009; Sitzmann, 2011).

The inherent difficulties in the study of immunology have been encompassed by Tanne (1990) with her quote:

> Immunology is an invention of the devil, who is making it up as he goes along because he's not too clear about this stuff either.

The immune system is a collective process of cellular and molecular interactions within an organism to protect it itself against negative outcomes. It is an essential element of many human body-associated studies including medicine, physiotherapy and alternative therapies. New terminology, interactions and reactions, systemic relationships and staged approaches for complex cellular insults (autoimmune diseases, pathogenic organisms etc) complicate mastering the concepts of immunology (study of immune system).

In 2004, secondary school teachers in the United States expressed a desire for assistance with teaching strategies specific for immunology curriculum. In 2004, The Federation of American Scientists lead a collaboration with immunologists (scientists studying immunology) and graphic art experts to design a computer video game to address this missing literature in learning and teaching for the future. The FAS (2009) developed program, Immune Attack™ has subsequently been downloaded by 9000 secondary school educators and has moved into an evaluation phase: measuring the impact and effectiveness of the game in controlled school environments.

Although there are divergent streams of game learning (game-based versus game-informed), the key is to ensure that learning remains fun and is an effective tool in helping students understand new sets of skills and knowledge that are applicable in related disciplines (anatomy, physiology, infectious disease etc)(Begg & Dewhurst, 2005). Game-informed learning places the participant not only at the decision making level, but also reinforces strategies, concepts and interactions within the context of the curriculum. Medical students are regularly exposed to such interactive programs that focus on curricula (simple game role-play) but also disease simulation (complex game role-play), which requires pertinent and correct decision-making skills to collectively meet the desired learning objectives (Kato, 2010).

Research goal

The aim of this research was to develop a computer game to teach immunology concepts and facts to students in an integrated fashion by incorporating theory, stimulating visuals and a hands-on approach. Our approach should promote learning for the future both in its methods of delivery and by appealing to a large student audience, being based around easily recognizable components which are fundamentally user friendly, yet achieve the desired learning outcomes.

Game prototype design and implementation

The prototype game that we have developed consists of three sequential levels, each of which introduces several new immunological concepts. The division of the material between levels reflects the order in which these events occur during the immunological response to an infection occurring in the body, thereby reinforcing students' understanding of the chronology of these events. Each level involves interactive gameplay inspired by some fundamental aspects of the immunological system – this is augmented by further detail supplied by pop-up notes and animations that occur in response to key events in the game.

Level 1 (Figure 1) covers the role of neutrophils in the initial response to an infection. The level uses Pac-Man™ inspired gameplay, with the student controlling a neutrophil as it moves through a maze-like environment of epithelial cells, consuming pathogenic (disease-causing) bacteria. The level ends when the neutrophil itself dies after consuming a large number of bacteria.

Level 2 (Figure 1) is based on similar gameplay to the first level, but covers content related to macrophages. It introduces the concept of Natural Killer cells, and the role that they play in increasing the activity of other macrophages – this is introduced via text notes, and then emphasized through gameplay by increasing the speed of the player-controlled macrophage when it encounters a Natural Killer cell.

Level 3 (Figure 1) covers the concept of macrophage rolling, and macrophage binding with selectins and integrins. This level uses a different gameplay approach based around a pseudo-3D visualization of the bloodstream. The student must steer the macrophage towards particular molecules (selectins) in order to interact and slow its progress before stopping completely by binding to a different molecule (integrin). This must be done whilst avoiding red blood cells, contact with which disrupts these bonding interactions and interfere with the slowing process. This game ends when players successfully slow the macrophage to the point that it can escape from the bloodstream.

Figure 1: Neutrophil response maze structure, protagonist and enemies (left), and the 'macrophage rolling' game (right).

The game prototype was implemented using Adobe Flash software. This enabled the production of script and animation assets to be performed in parallel, thereby shortening the development lifecycle. In addition the cross-platform, widely-adopted nature of Flash and the ability to embed it within a website maximizes the potential range of situations in which the game can be accessed, thereby increasing the likelihood of its uptake.

Methodology

To test the effectiveness of the prototype computer game, the research team recruited volunteer subjects from a second year undergraduate course in Immunology. Students were given a lecture on the 'innate immune system' that covered topics contained within the computer game. This group of students was then randomly divided into 2 subpopulations – those who would engage in 30 minutes of private study (tutorial) from the textbook, and those who would have 30 minutes to play the computer game. To ascertain the baseline knowledge prior to private study and the computer game session, both groups were asked to fill in a basic survey of knowledge with a series of short answer format questions based on content from the lecture. This same basic survey was repeated immediately after the conclusion of the private study (tutorial) and computer game session. The course coordinator graded the survey responses and student performance was ranked based on total score. The research team also examined volunteer groups of students without previous biological education: one group of first year biomedical science students who had not studied immunology, and one group of computer science students with no background in tertiary biology. These cohorts were used to judge the effectiveness of teaching difficult immunological concepts to those with minimal or no biological science background as a preliminary step towards modifying the material for secondary school audiences. The study design is shown in Figure 2.

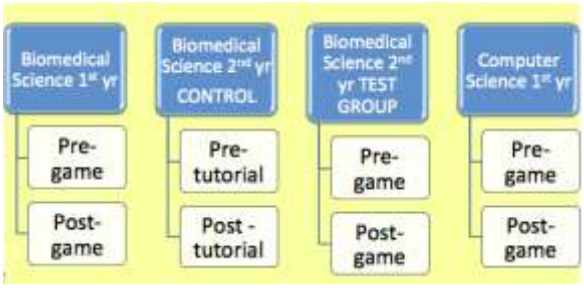

Figure 2: Study design flow chart

Discussion of findings

In the cohort of second year students studying immunology we observed equal increases in knowledge gained after playing the computer game as we did for private study (Figure 3). The increase in knowledge in each group was significantly greater than that obtained after lecture alone. We believe that this is an important finding as it provides statistical evidence for the effectiveness and further exploration for the efficient use and development of computer gaming in tertiary learning environments. It also indicates the ease in which carefully crafted and designed games-based learning tools can be incorporated into education to assist with tutorial and home-based supplementary study in an efficient manner (Ambrosio, 2012). The benefits that such an approach and extended learning environment can have to private learning could be immense as they provide a kinesthetic approach as well as the more traditional text-based and visual learning approaches, appealing to a wider variety of learners in an innovative way. Furthermore, we observed significant increases in knowledge in pre-game and post-game settings for the cohorts without the exposure to immunology lecture material. The capacity for the game to teach basic immunological principles to learners without a background in tertiary biological sciences is clear; this work paves the way for the introduction of the game into secondary schools to teach and promote the study of sciences at university.

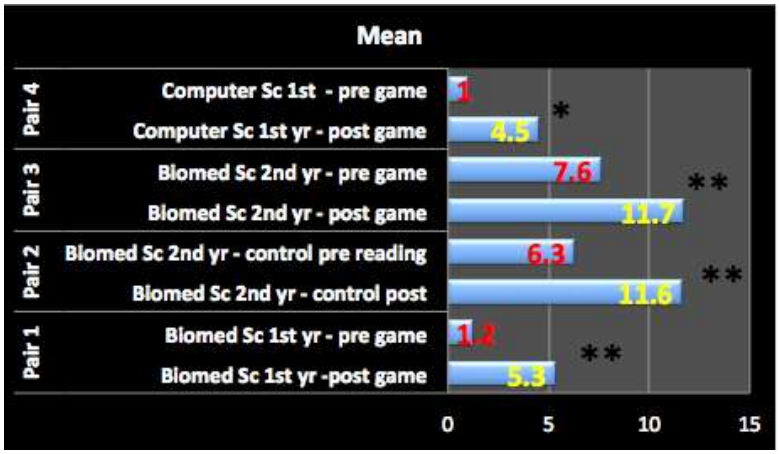

Figure 3: Mean student scores: pre-game and post-game scores (Pairs 1, 3 and 4), and control pre-reading and post-reading scores (Pair 2); * indicates significance at $p<0.05$, ** indicates significance at $p<0.01$.

Further dissection of the results revealed interesting correlations between the use of private study (tutorial) versus computer game learning style tools and their impact on test scores. There were very similar, strong correlations between the use of private study/computer game use and the improvement in test score evident in this study (Table 1). Conversely, only moderate correlations were observed between game use and improved test score in the computer science and 1st year biomedical science cohorts who lacked significant underlying biological knowledge. These correlations reinforce the notion that the use of the computer game in this study has contributed to improved test score, equivalent to the contribution of private study from the prescribed text-book.

Table 1: Correlation scores reflecting equivalent contribution of private study/computer game play to improved post-game test score

Cohort	Correlation
Biomedical Science 1st year	0.56
Computer science 1st year	0.44
Biomedical science 2nd year control group	0.90
Biomedical Science 2nd year game group	0.93

Limitations & conclusion

The key limitation in this study is a number of participants. We recognize the limited data obtained from the present study and consider this a pilot study for the future development of the game and research into its effectiveness. Population numbers in any given study group was not greater than 8 participants, and was just 5 participants for the targeted 2nd year undergraduate cohort. We will continue to research the effectiveness of the game as a study aid as new cohorts of students undertake the biomedical science program in an effort to boost the statistical significance of our findings. Despite these limitations we strongly advocate for the continual development, design and assessment of games-based approaches to teaching science related topics through all levels of education. We believe that innovative learning and teaching pedagogy approaches need to be relevant and add value to current student cohorts in an effort to build capacity learning opportunities in this health domain. With a national shortage of science-based healthcare professionals, educators need to be more innovative to attract potential secondary school leavers into this field and maintain their interest by further enhancing their learning capabilities within the higher education sector. A new era of learners should demand a blended new innovative approach to enhance the learning and teaching experiences for all future generations.

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