Augmenting learning of immunology through an online learning package and a digital game – what's next?

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Immunology, the study of the immune system, is a subject taken by tertiary life sciences students. It is perceived as difficult due to its technical terminologies and abstract concepts that are interlinked. To address these learning challenges, learning technologies were embedded into the curriculum of an immunology module. This paper describes the design, development and deployment of a digital game as well as an online learning package to enhance the learning of immunology. Key considerations in the incorporation of technology-enhanced learning into the curriculum are described. Student learning was enhanced, mainly through the animations and quizzes for the learning package, and the interaction and visuals for the game. However, not all students found the game engaging. Reflections on the effect of the learning technologies on student learning, sustainability and possible future directions will be discussed.

Keywords: immunology, technology, digital game, online learning

Introduction

Learning technologies are widely used in biological education, in the form of animations, visualisations, simulations, and so on as they can help to elucidate processes or phenomena that are otherwise invisible; e.g. DNA replication and techniques such as polymerase chain reaction (Lee & Tsai, 2013). Video games have also been shown to improve learning outcomes in education (Gee, 2003) and promote a positive attitude towards learning and school (Annetta, Minogue & Cheng, 2009).

Immunology is the study of the immune system and its response to infections. It is challenging to learn due to difficult terminology and complicated concepts that are interlinked. Moreover, the immune system responds differently to various pathogens and students require deep understanding to apply their knowledge to specific contexts. Digital games for learning immunology have been reported in the literature (Kelly, et al., 2007; Nankervis et al., 2012; Cheng et al., 2013). However, these games are either not available for public access, not in the English language or do not meet our intended learning outcomes. This paper outlines a technology-enhanced approach to augment the learning of immunology for students at Ngee Ann Polytechnic, Singapore. It comprises two complementary parts: an interactive digital game, "Mission: Immunity!" as well as an online learning package for explicit teaching.

Embedding technology in the learning of immunology

Development of a digital game, Mission: Immunity!

Rationale for development of digital game
A digital game was developed to provide an interactive and engaging learning experience to enable students to visualise and the processes and interactions of the immune system components and how they contribute to the 'big picture'. The game and its impact on learning has been reported (Low & Lim, 2017) and is briefly described below.

Immersive game-based learning
The game presents two game scenarios depicting infection by a virus (Influenza!) and a bacterium, (Pneumonia!). The student controls immune system components to accomplish game challenges. On completion of all challenges, the student unlocks a battle mode which opens a 'command centre' coordinating all immune responses to the infection concurrently (Figure 1).

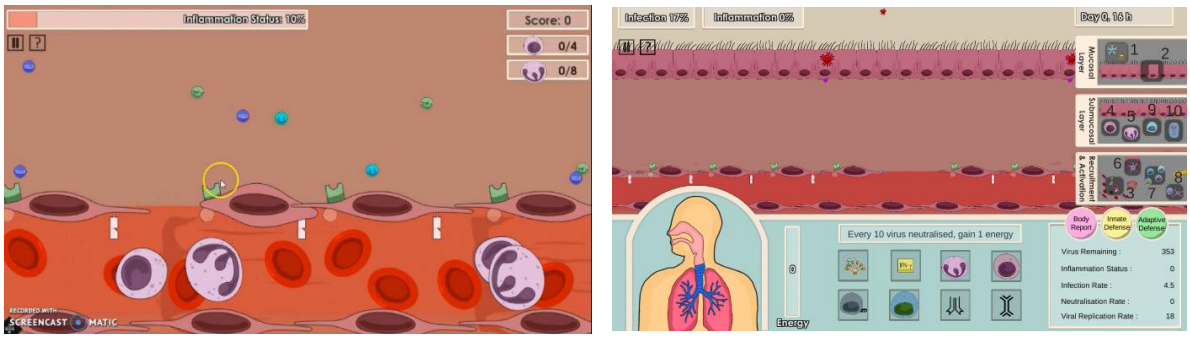

Figure 1. Gameplay mode (left) & battle mode (right) (https://bit.ly/30MUZPb)

Design of game to incorporate content learning
Content learning is embedded in the background information at the start of each challenge as well as the interactive game tutorial which provides step-by-step guidance for the challenges. Quizzes are incorporated after each challenge to make learning outcomes explicit and to provide feedback to students (Figure 2).

Figure 2. Background information (left), interactive game tutorial (middle) and quiz (right)

Development of an online learning package

Rationale for the development of an online learning package
As part of a push towards the development of online learning at the institutional and national level, part of the immunology module was selected to be developed as a 5-hour online learning package and made available on PolyMall, a learning management system shared by Singapore's 5 polytechnics, available to all polytechnic students. As PolyMall is intended to be self-accessed by any student, the online learning package was designed to be self-paced with no interactions with facilitators or other students.

Using online scenarios to facilitate learning
In conventional lectures, the immune system is taught in isolated parts from cells, proteins and organs, to processes. In the online learning package, the content learning is presented through scenarios, such as infection by the influenza virus (Figure 3) connects the different components. Students learn about the immune response through the analogy of a battlefield.

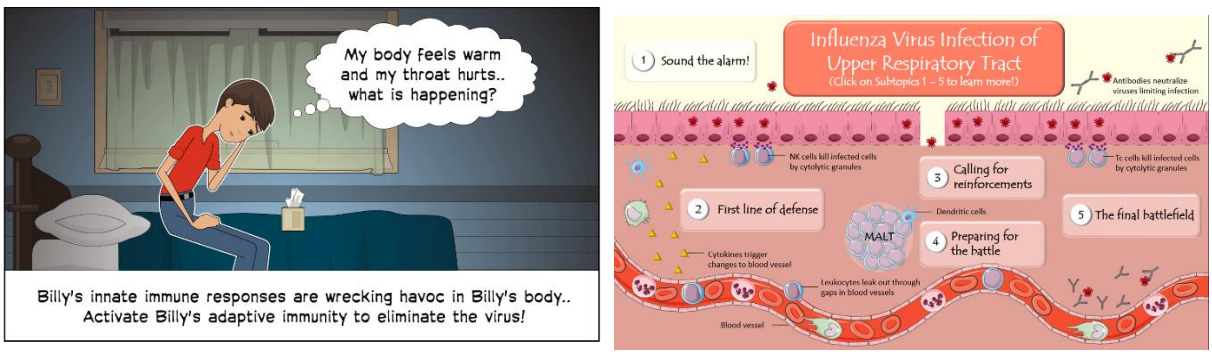

Figure 3. A comic illustration for Billy has the flu (left) and content selection page (right).

Enhancing the learning experience through incorporation of animations, illustrations and quizzes
Each topic commences with an animation that illustrates the stage of infection that will be covered in the topic; (https://bit.ly/2JISrMp). This allows students visualise the role of the immune system during an infection. Content knowledge was also explained through voiceovers and illustrations. Embedded quizzes help reinforce learning and clarify misconceptions.

Integration of online learning package and Mission: Immunity! into the curriculum

The online learning package was spread out over 3 weeks and students were given instructions regarding their online tasks on a weekly basis. A flipped learning approach was adopted, allowing students to discuss key concepts learnt the week before to deepen their learning. *Mission: Immunity!* was introduced after content knowledge was taught as our earlier study indicated a greater impact on learning after, as opposed to before formal teaching. To reduce the barrier of using a new educational tool, students were introduced to the game mechanisms and were tasked to complete 3 game challenges during a 1-hour classroom session. This also allowed for technical issues to be resolved. In addition, there was also social learning as students helped one another as they played side by side. Subsequently, students were required to complete the remaining challenges on their own in the next 2 weeks. A debrief session was carried out to reinforce the learning and clarify misconceptions.

Findings following implementation of online learning package and digital game

This two-pronged technology-enhanced learning approach for immunology has been carried out for 2 years. A learning experience survey was conducted upon completion of the online module (Table 1) and Mission: Immunity! (Table 2). A 5 point Likert scale was used. Up to 83% of the students had positive perceptions (score of 4 or 5) of the online module, while up to 72.7% of students in AY17/18 and 86.7% of students in AY18/19 had positive perceptions of the game.

Table 1: Results of online learning package (PolyMall) experience survey

PolyMall experience survey (48 responses)		*% Agree or Strongly agree*
1)	*The animation has helped me better visualise the immune system processes*	74.5
2)	*The quizzes have helped reinforced the concepts learnt*	83.0
3)	*Overall, the PolyMall module benefits my learning of immunology*	72.4
4)	*I find the PolyMall module interesting*	68.1
5)	*The PolyMall module has increased my interest in learning immunology*	53.2
6)	*I would like to recommend this module to others*	55.3

Table 2: Results of game experience survey

Game experience survey	*% Agree or Strongly agree*	
	AY 17/18 (n = 66)	AY18/19 (n = 30)
1) Playing the game has helped me to learn immunology terminology	59.1	73.3
2) Playing the game has helped me to better understand how the different immune system components work together	59.1	73.3
3) Playing the game has helped me to better visualise the immune system processes	72.7	86.7
4) Overall, the game benefits my learning of immunology	60.6	76.7
5) Playing the game has increased my interest in learning immunology	47.0	56.7
6) I find the game interesting to play	51.5	56.7
7) I would play the game again on my own	40.9	40.0

For the online learning package, students found the quizzes most useful for learning. This was also reflected in their qualitative comments; *"The quiz forced me to understand the concepts and that is good"* and *"The quiz after each subsection (helped me to learn)".* This is in agreement with studies that show quizzes have a positive and long-lasting effect on learning (McDaniel, 2011), through immediate feedback (Peat, 2002).

Visualisations were also perceived to be beneficial when students are learning via the online learning package as well as *Mission: Immunity!*, which also accords with the literature (Lee, 2013). Visualisations facilitate the understanding of biological processes and abstract concepts, thus enabling learners to gain a deeper understanding of the subject.

Reflections

Integration of online package and game with face-to-face sessions for enhanced learning

In the first semester that the online package was used, the online learning was carried out within a 2-week period without face-to-face contact, which led to a lack of connection between the students and the lecturer. Hence subsequently, a flipped learning design has been used. The online package is coupled with face-to-face tutorials, where students apply the concepts learnt and clarify doubts, and the lecturer is able to build rapport with students. As shown in Table 2, the game was not terribly engaging in itself, but it served its purpose of helping students to visualise the processes in an interactive manner. During the subsequent face-to-face teaching, explicit connections are made to the online package and game scenarios to illustrate key concepts.

Enhancement of learning: beyond engagement to improved learning outcomes

It is difficult to attribute improvement in attainment of learning outcomes specifically to the online package and game as there are many factors affecting the students' performance. However, there are qualitative indicators, one of which is the quality of questions asked by students. Prior to the implementation of the game and online package, students would ask questions that were more microscopic and atomised in nature, which showed lack of big-picture understanding. However, after the implementation, the questions were deeper in nature, showing greater appreciation of how the immune system works in an interdependent manner.

One concern with moving a portion of the learning online and having less face-to-face teaching was whether learning would be compromised, particularly for the weaker learners. Due to a change in the curriculum at that time, we were unable to compare performance across the cohorts. However, it was encouraging to observe that student performance remained healthy, despite a reduction in curriculum hours.

Technology considerations for the game Mission: Immunity!

The learning package will need to be updated or refreshed from time to time. This is not an issue as it was created entirely by the lecturers, using mainly Powerpoint and the iSpring authoring toolkit. The game, however, is a different matter. As the lecturers do not have expertise in game design and development, a vendor was engaged to develop the game. There was close collaboration to develop a game to bring across the learning objectives accurately, yet have game objectives. Maintenance of the game is required due to browser updates and security vulnerabilities over time. However, the 3-year maintenance period of the game has ended, and the vendor has changed the focus of its core business. Although the source code is owned by the institution, it will be difficult to find another vendor that would continue to maintain the programme. In future, when the game becomes obsolete, it may be more feasible to redevelop the game than to patch it. However, this would incur significant cost and hence, for a greater returns on investment, the user base should be expanded.

Scaling and sustainability; collaboration with other institutions

Currently only the online learning package is available to students and lecturers from the other polytechnics. However, usage by other students is very low. To encourage adoption, it may be necessary to reach out to lecturers and include a resource pack such as accompanying slides and lesson plan and guide for lecturers.

The game would complement the learning package very well. However, it is currently not deployable on the PolyMall platform for sharing across the polytechnics. While the game is browser-based, it has to be launched from an in-house server and database, as student access and progress is tracked. This presents challenges as it can only be used within the campus or via a virtual private network. One possible solution is to host it on the cloud, but there is a running cost to be borne. Another possibility is to open the game for public access and not track individual progress. However, the issue of administration of accounts, maintenance and cost would be a limiting factor, as the risks of hacking and vandalism would also be increased.

What's next? A different paradigm?

During the development of this game, another game for learning immunology aimed at college-age students, *ImmuneQuest* was developed (http://immunequest.com/). The game was conceived by scientists and technologists, with support from the National Science Foundation. As at this point in time, Part 1, which covers innate immunity, is free to play, while Part 2 requires payment, to fund the development of the remaining Parts 3 to 5, which are yet to be developed. The game has an educator's portal which allows the lecturer to provide students with a course code and track their progress. A study carried out with undergraduates found that the game aided learning of immunology (Raimondi, 2016). Once *Mission: Immunity!* reaches its end-of-life, it may not make sense to redevelop it, if high quality games that meet the leaning outcomes such as *ImmuneQuest* are available.

However, there may be a potential for developing a game in which teachers and students can create challenge scenarios. The concept would be similar to visual programming software such as Scratch and other drag and drop programming tools. Immune system components have certain behaviours and characteristics, and there are a limited number of arenas (parts of the human body) in which they act. By developing a sandbox for the immune system where lecturers could programme the parameters of a particular pathogen, sites of action and their interactions of the immune system, would allow lecturers to develop their competencies in game-based pedagogy (Nousiainen, 2018). If this is open on the web, the immunology community could contribute different scenarios, as seen on the Scratch website (https://scratch.mit.edu/)

Taking this further, the next step forward would be student-authored games. Beyond playing games to learn, creating games based on the learning or research sets the stage for deeper learning as students extend their learning from the learning packages to create their own scenarios. Apart from deeper learning, students could also develop critical thinking skills (Yang & Chang, 2013) and computational skills. While Mission: Immunity! is a single-player game, game authoring involves groups and is a social constructivist approach to learning through collaboration (Kafai, 2015). Students could create games based on actual pathogens on which they carry out research. This also opens up possibilities for assessment of learning as students demonstrate learning through game creation. Peer assessment could also occur through playing games created by other students and providing feedback on the games. We propose that this would be a future direction for deeper learning of the immune system.

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Please cite as: Low, P.Y., Teoh, C.M. & Lim, G.B. (2019). Augmenting learning of immunology through an online learning package and a digital game – what's next? In Y. W. Chew, K. M. Chan, and A. Alphonso (Eds.), *Personalised Learning. Diverse Goals. One Heart. ASCILITE 2019 Singapore* (pp. 503-508).