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The Cell Cycle: Development of an eLearning Animation

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The use of eLearning resources is becoming increasingly widespread in medical education because of its numerous advantages. They awaken interest in students, can be reused without loss of quality and give students added control over their own education by allowing them to review content in their own time. This article describes the development and evaluation of an innovative eLearning animation for the curriculum of the pathology class at the University of Dundee School of Medicine.

Keywords: eLearning; education; cell cycle; animation

Introduction

Medical students face an extensive and time-consuming curriculum. They must learn about challenging topics, which can have a negative impact on their interest and motivation. This article showcases the development and evaluation of an innovative eLearning resource as a complement to the curriculum of the pathology class at the University of Dundee School of Medicine.

Educational Context

Current medical school curricula face the challenge of having to deliver increasing levels of knowledge in shorter time frames. Furthermore, earlier introduction to clinical exposure disrupts the delivery of basic science teaching, which formerly, several of the first years of medical school were dedicated to. One such subject is pathology where students learn the basic processes that cause many diseases. Integral to an appreciation of many diseases such as cancer is an understanding of the normal cell cycle. This encompasses the cellular processes that most occur before a cell can divide. This is no simple mechanism and involves complex events at a cellular and molecular level. Such a level of complexity delivered in a short period of time can be daunting to students and is often a large disincentive to learn the subject well. Moreover, when initially encountered the clinical relevance of the subject can be difficult to discern further discouraging students from the subject.

The cell cycle is, however, very clinically relevant. Important events in the cell cycle are often the source of errors that can lead to cancer development, often in association with inherited forms of cancer. As our understanding of these events improves they have begun to form important targets for many cancer drug treatments.

Because the cell cycle follows a specific pattern in a very temporal fashion, it was thought that an animation would be appropriate to present the topic to the students. Although there are existing animations representing the cell cycle, most of them are based on the classic representation of the cell cycle as a circle. We aimed to engage students by presenting the information in an innovative and unique context, specifically as a videogame (Figure 1). The popularity of video games amongst students and the evidence that suggests more engagement towards learning when these resources are used (Kili, 2005; Annetta et al., 2009) both supported the initial idea of simulating a video game with the present animation.

The video is intended for use in conjunction with teaching rather than as a stand-alone resource. Initially the subject matter and basic concept is introduced as part of a lecture. The animation was then introduced after short segments of the lecture to reinforce the teaching and present the temporal aspects of the concept in an accessible and logical fashion. By doing so it was possible to highlight the clinical relevance of the subject and answer any questions that arose from the animation. Research shows that animations can increase engagement and prompt more questions from the students (O’Day, 2007) and that having an in class discussion helps better understanding of concepts (McClean, 2005; Yarden, 2013).

Animation in Science and Medical Education

University students are continuously exposed to a technology-rich environment. Because of this, their attention span has shortened and they do not respond as well to traditional instruction (Prenski, 2001; DeCastell and Jenson, 2004). For this reason, educational developers are being encouraged to use eLearning resources to make lessons more engaging for modern students (Adams, 2007). Students are very familiar with the involved technology and numerous studies have shown that eLearning can result in a more positive attitude of students towards their learning experience (Broering and Lilienfeld, 1994; Thatcher, 2005; O'Day, 2006; Adams, 2007; Singh, 2009).

The development of new technologies and the availability of computers, tablets and smartphones is increasingly widespread, and so are the techniques to incorporate them as an instructional advantage (Kim et al., 2007). Furthermore, the use of eLearning offers learners, to some degree, control over the content, learning pace, time of learning and much more, so they can tailor their experiences to meet their personal learning objectives and methods (Ruiz, 2006). These attributes suppose a clear advantage over traditional teaching methods, and should be considered when designing the educational curriculum.

A number of studies have shown that students who learn with animations as opposed to traditional lectures obtain significantly higher marks and improve performance (Stith, 2004; O'Day, 2007; Trevisan, Oki and Senger, 2009; Yarden, 2010; Onita, 2015). Additionally, a recent meta-analysis showed that dynamic visualizations are better at enhancing learning than static pictures (McElhaney, 2014) and a study showed that students who watched animations as supplementary learning material were increasingly interested in the subject of learning, understood complex concepts better and demanded similar resources for other challenging topics (Hwang, 2012).

Animation of the Molecular World

Animations offer very clear advantages over direct or indirect observation of the cellular and molecular world: simplification, unlimited resolution and magnification, control of motions, changes in shape and colour, the ability to highlight certain elements within a complex background and the stepwise appearance of symbols and labels (Stith, 2004). Details can be shown from angles or at scales that are not feasible in real life and in a way that is more comprehensible for students (Hwang, 2012). Additionally, the same content can be shown in various degrees of complexity depending on the purpose or the target audience of the resource.

A further advantage of animations is that, because movement and changes in size or form can be depicted in a literal way (Stith, 2004), there is less need for interpretation as compared to a picture with arrows and other symbols trying to represent these changes, which have to be inferred and processed with the rest of the information (McClean et al., 2005).

The Cognitive Load Theory and the Theory of Multimedia Learning

The Cognitive Load Theory (CLT) and the Theory of Multimedia Learning (TML) provide a well-researched insight as to how people learn from words and pictures. Cognitive research shows that animations can promote learning and understanding when they are consistent with the principles of both theories (Mayer and Moreno, 2001). These principles explain what makes an effective educational animation and why some animations fail to produce better results in learning than static pictures. Both theories impacted the decision making process while creating the present animation.

CLT suggests that working memory can only accommodate limited information at a time. When this limit is exceeded, cognitive overload occurs and this in turn impairs learning (Verhoeven et al., 2009). The principles of CLT are oriented towards reduction of the cognitive load where possible to ensure that the learning resource aids learning rather than making it more challenging. There are three categories of cognitive load: extraneous, intrinsic and germane.

Intrinsic cognitive load is largely determined by the topic itself. It depends on the number of elements and interactions present in it. The cell cycle includes comprises high number of both, and therefore has high intrinsic cognitive load. The initial idea was to explain both the normal cell cycle and its clinical implications in tumour formation in the same animation, which has an even higher cognitive load and could easily lead to cognitive overload, hence impairing learning. Although intrinsic cognitive load cannot be manipulated by the instructional designers (Höffler and Leutner, 2007), research has shown that animations that contain more information than is appropriate are not very effective (Tverski and Morrison, 2002), and that for complex processes it is wiser to break up the content into small packages rather than attempting to cover it all with a single animation (O'Day, 2008). Taking all of this evidence into account, it was finally decided to restrict the content of the animation to the normal cell cycle. Even if this did not actually reduce the intrinsic cognitive load of the subject, breaking down a complex subject into more manageable units alone should make learning easier.

On the other hand, extraneous and germane load are mostly dictated by the instructional design (Paas and van Gog, 2006). Extraneous cognitive load is innefective for learning and is determined by how the animation is presented. Thus, a good choice of the instructional format can reduce extraneous load (Koning et al., 2007). Studies have shown that animations are generally more effective in terms of reducing the cognitive load rather than a comparable series of static pictures, especially when visualizing a series of events that occur in a certain order in time, because they can show steps in an orderly manner (Hwang, 2012).

Finally, germane cognitive load refers to the effort that has to be put into processing, automating and construction of permanent knowledge. It is effective for learning and should be promoted to enhance it (DeJong, 2010). The extra cognitive capacity that becomes available when extraneous load is reduced can be devoted to activities that further contribute to learning. This project aimed for a reduction of the extraneous load by choosing an animation over static pictures for a dynamic and stepwise project that otherwise would involve numerous arrows and symbols that would require interpretation by the learner. Extraneous load was further reduced by making the animation interactive. It has been shown that interactivity increases the efficacy of animations (Mayer and Moreno, 2002; Stith, 2004) because the viewers can watch the animation at their own pace. Interactivity can be as simple as the ability to pause, play, rewind, fast forward or scrub.

The theory of multimedia learning (TML) builds on the dual channel assumption by which humans process new information via two separate but interdependent pathways: visual and verbal. Principles of TML dictate how to make an animation effective in terms of knowledge transfer and learning enhancement. These have been followed during the development of the animation:

- Multimedia principle: a narration of the events has been included in the animation because this is more effective than animation alone.
- Spatial contiguity principle: labels appear close to their corresponding elements rather than far away.
- Temporal contiguity principle: actions occur simultaneously with narration rather than successively.

- Coherence principle: extraneous words, sounds or video have been excluded to prevent the learner from paying attention to irrelevant elements.
- Personalization principle: the narration is presented in a conversational style, which is more effective than a formal tone.

Methods

Pre-production

The creation of an animation involves pre-production and production phases. The pre-production phase is the time before any animation takes place. The aim of this phase is to draw up a plan in which the production phase is based. This includes discussing key elements such as the content and style of the animation, the learning objectives, the target audience the tone of the narration and the duration. The purpose of this plan is to ensure that the project stays on track, covers all learning messages and does not expand on what was initially planned, since this might result in a cognitive overload.

The pre-production phase also included thorough research on the cell cycle to ensure the scientific accuracy of the resource and summarize the content to avoid excessive detail but without excluding any of the essential information that the students need to learn according to the curriculum.

Production Workflow

The production phase consists on the animation of the scenes. During production, three computer programs were used: Adobe Illustrator CC ®, Adobe After Effects CC ® and Adobe Premiere CC ®.

Adobe Illustrator CC ®

This is a vector-based graphic design program that allows the use of shapes and paths to create artwork. One of the main advantages of using a vector-based program is that, because vectors are based on mathematical equations rather than pixels, artwork can be scaled to any size without loss of quality. Adobe Illustrator ® was used to create all the graphic elements, including characters, objects and backgrounds. A flat style with no 3D perspective or gradients was used because it made the aesthetics appealing without adding too many details that might distract students from the key messages of the animation. The aim was to achieve an aesthetically pleasing and clean final look (Figure 2).

Adobe After Effects CC ®

Adobe After Effects CC ® is a motion graphics, visual effects and compositing application. This program was used to add movement to the graphic elements that had been created in Illustrator. One of the main advantages of working with these two programs in combination is that any changes made to the graphic elements in Illustrator will automatically update in After Effects, so that modifications can be made at any point during the animating process if needed.

Adobe Premiere CC ®

This final program was used to add the narration, music and sound effects to the final animation. The narration had a conversational tone and was coordinated with the movements on screen and the appearance of labels, following two of the principles of the Theory of Multimedia Learning. These labels, also according to the TML, appeared next to their corresponding objects. Additionally, some sound effects and glowing were added as auditory cues to direct the attention of the viewers towards key events in the animation (Figure 3). It has been shown that cueing helps allocate working memory resources towards learning more efficiently by guiding attention to the relevant aspects of a learning resource (Koning et al., 2007).

The final animation was rendered in Adobe Premiere ®.

Feedback Survey

It is important, once an eLearning resource such as this one has been produced, to subject it to evaluation by the target audience. In this way, suggestions and feedback can be incorporated to future projects to ensure that they are even better adjusted to the learning needs of the students and the teaching repertory of the lecturers.

In order to evaluate this animation, an online survey was created using Survey Monkey and sent via email to students and lecturers of the University of Dundee School of Medicine. This included medical students from first to fifth year and any staff involved in the teaching of basic sciences at the School of Medicine. A total of 21 participants completed the feedback survey

Results

The final product was a high-quality QuickTime ® animation with a duration of 03:57 minutes, viewable across many devices, including computers, tablets and smartphones. The animation was uploaded to the University of Dundee Technology and Innovation in Learning Team (TILT)'s Vimeo channel, where anyone can access it online at any time (Figure 4). One of the authors (RO), was provided with a file for incorporation in his lectures, as the animation works best in conjuction with teaching rather than as a standalone resource. Later on, students viewed the animation again in their own time if they wished to refresh their knowledge or spend more time on a particular section of it. Furthermore, they could expand on their knowledge by complimenting the key messages given by the animation with more detailed information found in textbooks or other resources.

Additionally, from Vimeo, the animation can also be liked, shared and added to collections, as well as published across many other applications. This gives an added value to the project by significantly increasing the University’s presence in social media.

Feedback Survey

As stated, in total there were 21 responses to the feedback survey Overall, there was a positive response towards the animation and this is reflected in some of the students’ comments:

‘Very engaging and entertaining’, ‘Well narrated and covered all the relevant elements of the cell cycle.’, “Visually appealing.”, “I liked the format as a game, it makes it easy to remember.”, “Interesting and memorable.”, “Clean sharp graphics, high quality.”, “I enjoyed the colours and how the animation made the cell cycle easier to understand.”

Some students made suggestions for improvement of this and future resources, such as the addition of subtitles and a short summary of the key messages at the end of the animation. Additionally, most of them also asked for similar resources to be produced to cover other challenging topics of the curriculum, including activation of B and T cells, apoptosis pathways, biochemistry, cancer, the causes of jaundice, the cough reflex, disease pathophysiology, ECG, electrolyte imbalance, haematolgy, the Krebs cycle and many more.

Discussion and Future Work

The feedback results indicate a predominantly positive reaction from participants towards the animation. Overall, participants agreed that it had helped increase their knowledge about the cell cycle and said that it was entertaining, understandable and easy to follow. However, it should be noted that the video-game style does not appeal to all participants, possibly because of the additional effort that has to be made by the viewer to relate the video-game metaphor with the actual cellular processes. A solution to this might be to explain the nature of the video to students prior to viewing and to clearly illustrate or explain what each element represents. Similarly, two participants who were already extensively familiar with the cell cycle prior to viewing the animation said that it had confused them. Upon research of similar studies, it was found that students who are extensively familiar with a topic might find animations redundant because they might interfere with their already constructed mental schemas (Ruiz, 2009). This might explain why the animation was not helpful for these participants.

Students consistently stated that they would like more animations to be used in teaching, and most of the suggestions made by students were aimed at improving the educational value of the animation. This shows positive interest towards this and future similar resources and suggests that animations are an appealing way of complimenting the curriculum.

Given the feedback, we would like to explore relationships between the level of understanding of students and the style of animation. We would aim to assess whether preferences relating to the style of presentation are influenced by background levels of understanding or simply relate to personal issues of taste. Future work would also be aimed at interpreting other subjects suggested by students for presentation as animations.

Conclusion

The purpose of this project was to create an innovative educational resource about the cell cycle to use as a complementary teaching resource in the pathology class at the University of Dundee School of Medicine. The animation that was created adhered to both the key learning objectives of the class and the principles of the current theories concerning educational animations: the Cognitive Load Theory and the Theory of Multimedia Learning. This resource awakened interest in students and constitutes a positive addition to their learning experience. It enables them to learn actively rather than passively and gives them added control over their own education. Furthermore, they were able to voice their opinions through the online survey. In this way, they have been empowered to contribute in shaping their own learning tools and actively help future medical artists create resources that adjust even better to their needs.

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Figure 1. Representation of the cell cycle phases as different ‘worlds’ in a video game style.

Figure 2. Final look of the graphic elements created with Adobe Illustrator CC ® in a simple flat vector style.

Figure 3. Scene of the animation showing labels next to their corresponding elements and visual cueing in the form of glowing.

Figure 4. Final animation in the University of Dundee TILT’s Vimeo channel.