Design and Development of a Serious Game for Medical Training in Cytopathology

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We are designing and developing a serious game for cytopathology medical training. This game has some challenging technical requirement as to be deployable both in PCs and in low-cost Android tablets (e.g., 50$ Kindle Fire 7 tablet) with a limited budget. We reviewed some of the existing games or gamified e-learning modules to create a shared understanding between medical experts and developers about possible game mechanics and to identify which of those approaches can be suitable for our case.

There are numerous examples of games and game-like approaches successfully used in education. Those games are called “serious games” as their main goal is not only entertainment. Serious games for health have been increasingly used in the past years and there are examples in very different areas as games targeted at HIV prevention education, cancer diagnosis, dental pain, etc. and both for training medical personnel or oriented to patients [2].

In our project we want to create an educational game that can be used as a supplement to content for an Introduction to Cytopathology course. But, the use of serious games to train medical personnel in cytopathology is still a relatively uncharted field. Our project has a limited budget and some challenging technical requirements as the game should be also aimed to train cytologists in resource-limited areas of the world. That means, for instance, that the game should run in low-cost Android tablets and be fully functional without requiring continuous Internet connection.

The educational approach is focused on training the medical personnel in medical microscopy. The ability to morphologically identify normal and abnormal cells and to locate rare abnormal cells among many normal-appearing cells is the most difficult for cytotechnology students and pathology residents to learn. The learning objectives are to be presented in a gamified way, offering exciting, innovative, and effective methods for increasing the knowledge of the learner. Knowing which story and game characteristics (e.g. game mechanics) appeal to specific types of people would help tailor game design and behaviour change procedures to maximize effectiveness.

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Furthermore, implementing the gaming platform must be done taking in consideration different key technical project requirements such as the target resolution for Android tablets and PCs, code maintainability, applications design, etc.

A specific analysis of serious games for medical training was needed to obtain specific game mechanics that could be useful for our project. For instance, in our case all the assets of the game must be packed with the game and cannot be downloaded dynamically, which may imply size-related concerns for the Android version of the game. Most existing games use an Internet connection (not suitable for our project) and are executed on PCs where the size of the game and its assets did not pose a technical problem. We decided to review specific games and applications that have been used in medical education to train expert and non-expert personnel in domains relying on medical microscopy.

MalariaSpot is a game-like application oriented for crowd sourced collaboration in the diagnosis of malaria done by non-medical experts [1]. The objective of this game mechanic is to tag in a given amount of time as many intracellular parasites as possible in an image of a peripheral blood smear. There is an initial introductory mini-tutorial screen explaining what a parasite is and what is not and how to interact with the image. During the game, if the player finds all the parasites of an image in the allocated time, a new image will be loaded up. Each image should be considered as a level of the game, therefore, a player can analyze several images (levels) in a single game. There are several game mechanics to reinforce the player engagement. Firstly, the players receive continuous feedback. For instance, each click is represented with an icon that indicates a correct or incorrect selection. Furthermore, if a player misidentifies a target and clicks in the wrong one (e.g. on a leukocyte) the penalty is a reduction of the remaining time available and the final score of the level. The players' score is tracked on a leader board.

In our case, image size may pose a technical problem for the tablets video memory, especially if the image is very large. A possible solution can be to slice the image in multiple tiles that are used to render the entire map. The tiles can be loaded and unloaded from the graphic memory dynamically as they are shown in the screen or hidden.

The Cytopathology virtual microscopy adaptive tutorials (VMATs) use an adaptive e-learning platform that includes whole slide images for pathology education and training of both students and specialists [6]. VMATs are designed to “adapt” to the user's decision-making and aid with possible misconceptions through immediate feedback. The gameplay is composed of a text-based question on one part of the screen and a related image (slide) on the other side of the screen. There are several mechanics that provide a game-like behavior enhancing the gamified interaction. Firstly, the question format changes (e.g. multiple-choice, drop-down lists, drag and drop type questions, fill-in-the-blank). Furthermore, immediate feedback is provided based on the learner's responses with more information about the quiz or about a specific area on the slide.

The VMAT approach can be reused in our project as it is oriented to cytopathology and it takes as a content starting point a set of teaching slides. But VMATs are only for PC and rely on a continuous Internet connection as data is continuously collected from these interactions for adaptive purposes and to provide evidence about the effectiveness of the quizzes. The size of the slide image may also present technical problems for the tablet hardware. A possible solution is to reduce the size of the slides to an acceptable level. VMATs were created using an intelligent tutoring system called AeLP (Adaptive eLearning Platform) that is completely web-based and eases the development of adaptive learning materials. Even though there are several applications and simulations created using the AeLP (e.g. VMATs or the Western Botting vLAB [4]), those applications do not meet the requirements of our project, since they rely on a stable Internet connection and are not optimized to be displayed on low cost Android tablets. But of course there are some design choices that can be reused. For instance, the way to integrate introductory information inside the formative experience, how the tasks are associated with questions and how different media is embedded within the user interface (e.g. interactive images) to enhance the student learning.

BioGames is a training game that helps identify malaria infected cells [3]. The game has an introductory tutorial and challenges the player to identify infected and uninfected cells. For each level a set of cells is displayed to the player. The player has to label the available cells either as "positive", "questionable" or "negative". Players receive a score depending on their performance labeling cells. There is also a progress bar as a visual feedback and the players' top scores are integrated with a leaderboard system to promote competition and to improve engagement. Furthermore, this type of game mechanics can be easily integrated with an analytics tracking system to collect useful interaction data.

To reuse a similar approach in our game we must consider the size of the final game. Since all the images must be packed inside the game (cannot be downloaded dynamically), the number of cell images available to the player might increase the size of the game considerably. This might become a problem for Android devices.

Cell Slider is a game developed in collaboration between Cancer Research UK and citizen science experts Zooniverse [5]. The players must examine tumor tissue samples images and identify cancerous cells by answering simple questions about what they see in the image. To increase the validity of the answers, several people review the images. Cell Slider ask its players to identify specific items in tissue samples images and includes quiz challenges composed of text-based questions and a related image.

From this review we observe there are very different approaches and game mechanics that can be identified as best practices and reused or adapted for the design of a new game or game-like application to train medical personnel in the analysis of medical images for cytopathology.

We have concluded that one possible design could be presenting the learner with a short story to set up the context, followed by a concise tutorial explaining the game mechanics and ending with the player having to overcome different challenges (i.e. levels) that can be measured to assess the learner's progression. A challenge, in its simplest form, could be a multiple choice question about a concept, an image or a specific region of an image where the user should identify if there is any anomaly or special circumstance. There could be a set of challenges, questions or puzzles from which a randomized sample is taken every time the learner starts playing a session. The challenges may also vary in difficulty as the learner advances and could have a gamification metric associated (allowing the creation of rankings between players) increasing the content diversity for each gameplay session. This design presents the content as a progression of events - initial story, basic concepts description, progressive challenges - that can be easily understood by the player. The initial story provides a supporting narrative meant to address the learner's motivation and interest. This initial design should be aligned with the specificities of our project.

Some of the analyzed systems capture user interaction data with different purposes (e.g. adaptation, leaderboard) and we consider that this is the correct approach even if in our case the game deployed in tablets cannot rely on a continuous Internet connection.

To conclude, we believe that the review done and the conclusions obtained about designing serious games for medical training in Cytopathology provide a solid ground for developing our prototype, as part of the early stage of a PhD. Next steps in the project are the completion of the initial prototype and the evaluation with medical students at the Harvard Medical School.

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2. REFERENCES

1. Miguel Angel Luengo-Oroz, Asier Arranz, and John Frean. 2012. Crowdsourcing malaria parasite quantification: An online game for analyzing images of infected thick blood smears. *Journal of Medical Internet Research* 14: 1–13.
2. Elizabeth J. Lyons. 2014. Review of Games for Health: Proceedings of the 3 rd European Conference on Gaming and Playful Interaction in Health Care. *Games for Health Journal* 3, 1: 49–52.
3. Sam Mavandadi, Steve Feng, Frank Yu, Stoyan Dimitrov, Richard Yu, and Aydogan Ozcan. 2012. BioGames: A Platform for Crowd-Sourced Biomedical Image Analysis and Telediagnosis. *Games for health journal* 1, 5: 373–376.
4. Patsie Polly, Nadine Marcus, Danni Maguire, Zack Belinson, and Gary M Velan. 2014. Evaluation of an adaptive virtual laboratory environment using Western Blotting for diagnosis of disease. *BMC medical education* 14, 1: 222.
5. Mark Schrope. 2013. Solving tough problems with games. *Pnas* 110, 18: 7104–7106.
6. L. Van Es Simone, Wendy M. Pryor, Zack Belinson, Elizabeth L. Salisbury, and Gary M. Velan. 2015. Cytopathology whole slide images and virtual microscopy adaptive tutorials: A software pilot. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4629310/