Game Based Learning of Blood Clotting Concepts

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***Abstract*— In this paper we describe the architecture of virtual clot (vCLOT), a virtual world system designed to teach procedural knowledge of blood clotting process, in a game based learning environment. vCLOT utilizes virtual world to give learners an immersive learning experience while actively participating in tasks that require them to apply the procedural knowledge they have learned. Design of vCLOT combines the immersivity of virtual worlds with the power of knowledge structures. Immersivity provides learners with the opportunity to make decisions at every level of the game. This transfers control of interaction to the learner, enabling the learner to be actively engaged in knowledge construction process. Knowledge structures are a neat way to represent domain and learner data. The user interface of vCLOT is designed and implemented with Open Wonderland which is an open-source 3D toolkit. The learning goal which is to learn about blood clotting process, is aligned with the game goal, which is application of blood clot process steps to heal an injury. The game goal is presented as a quest in which the learner interacts with concepts by either dragging them or synthesizing them from other concepts. Learners complete the quest on successful formation of blood clot which in turn implies that they have learnt the blood clot process. We plan to do a usability study to improve the system before starting actual intervention.**

Keywords- Game Based Learning; Procedural Knowledge; Blood Clotting; Open Wonderland; Quest

I. INTRODUCTION

Blood clotting process is an integral concept of human physiology, taught at high school level. Traditionally, it is taught as a series of steps. This could lead to a tendency towards memorization with no deep conceptual understanding of the underlying process steps. Even at high school level, it is worth delving into details such as identifying the chemicals involved in each step (such as thromboplastin, calcium ions), the sequence in which these chemical reactions are triggered and so on.

Teachers have also used videos and animations to teach physiological processes. Animations have the affordance of making invisible processes visible to learners, a quality that has been found as desirable while teaching about anatomy and physiology of the human body.

In this work, we have developed a game based learning environment- virtual clot (vCLOT). In vCLOT learners learn and apply steps of blood clot process in a virtual world. Our work extends the benefits of animations by (1) providing an immersive and situated learning environment, (2) providing more control to the learner in the learning environment.

The design of vCLOT combines the immersive nature of virtual worlds with an engaging game based learning environment. A well-defined knowledge structure at the backend links concepts, procedures and their relationships. Knowledge structures provide a means of capturing learner's knowledge by linking the activities of the learner to the concepts and procedures. In this way, knowledge structures help the researcher track learner's knowledge gain over multiple game attempts.

In this paper, section 3 describes how learner navigates through the game and learns in the process. Section 4 describes the design and architecture of vCLOT followed by a usability study plan in section 5.

II. RELATED WORK

Blood clotting process involves multiple concepts and procedures. The interaction between concepts are captured in the procedures thereby intertwining conceptual and procedural aspects of blood clot process. For instance, "Thromboplastin", "Prothrombin", "Calcium ions" are concepts and the reaction between Thromboplastin and Calcium ions to form Prothrombin, is a procedural step.

At high school level, it is desirable for learners to have procedural knowledge of blood at apply cognitive level. Learners are expected to be familiar with the concepts involved in blood clotting process. This includes ability to recognize basic steps associated with the clotting process. Learners would gain a deeper understanding of the process if they are exposed to problem scenarios wherein they need to apply knowledge about the blood clotting process to solve the given problem [1].

Traditionally, in lectures, physiological processes such as blood clot formation, is taught as a sequence of steps. This could lead to memorization without deep understanding. Other visually rich ways employed for teaching such procedural knowledge are using videos, animations and simulations. While videos and animations offer learners with interactivity restricted to play, pause, zoom-in, zoom-out, simulations offer greater learner control. Virtual frog (Vfrog) is one such simulation application for learners at school level. In this simulation, learners dissect a virtual frog (Vfrog), to learn about frog anatomy [2]. Another effective

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way of learning physiological processes is to use virtual worlds.

Virtual worlds offer some attractive affordances such as situatedness, and immersivity. While situatedness leaves the learners with an impression of participating in a realistic scenario, immersivity enables the learner to wear the decision maker hat, effectively putting the onus of the outcome of the game squarely on the learner. In addition, virtual worlds also support interactivity and visualization of invisible microscopic objects. These affordances are common to simulation also. Because of the above mentioned affordances virtual worlds are considered well suited for education. One of the virtual world is the "Rainforest Research Island", where learners explore the complexity involved in conservation of biological diversity in a tropical rainforest [3] . Virtual worlds have been widely used in different fields of medical education, especially in surgical training and diagnostic assistance [4]. Here, virtual worlds provide a safe way to get familiar with medical practices involving human body. Another virtual world environment-Second life allows learners to have avatar based interactions, including navigation in 3D space, synchronous communications, social interactions and community learning [5].

In the last decade there has been significant increase in the number of games that are being used in the context of education. In a well-designed educational game, game goal and learning goal should be aligned. Also it should motivate learner and provide personalized learning activities [6]. Generally in educational games, in order to progress to higher levels, learners are required to solve a series of problems with increasing difficulty levels. A popular game based learning environment in genetics is Geniverse which focuses on creating Drakes (virtual model species). Here, learners are required to apply different concepts of genetics such as heredity, gene, alleles, meiosis and so on in the game activity. Learners derive their findings using argumentation, and support their claims with evidence and reasoning. These games help learners learn complex concepts for specific subjects and skills in a situated and friendly environment [7]. Such wide acceptance of game-based learning motivates us to focus on the use of virtual world as a game-based learning environment for teaching learners procedural knowledge.

A game based learning environment requires a strong backend support in the form of a game engine. The game engine typically has information about the entities or concepts in the game, their properties, and their interactions in addition to the learner profile. Knowledge structures offer a neat way to store such information. Knowledge structures may hold detailed information of the concepts used in the game, their relationships with other concepts, examples, equations and principles if necessary, in the form of a concept map which forms the domain model. Knowledge structures may also hold details of learner interactions with concepts in domain, game based collectable objects which map to concepts in the domain model, number of attempts, points won and so on forming the student model.

Knowledge structures therefore can provide an effective way to capture learner's knowledge level and track learner's progress through the game. Knowledge structures have been employed in virtual world environments as well as game based learning environments. Pecunia is a virtual world based learning environment for finance education [8]. Knowledge structures have also been used in a context aware multi-agent based mobile educational game that generates activities for training in management studies [9]. Therefore knowledge structures are a viable means of storing information that needs to be retrieved or modified in a virtual world game based learning environment.

III. The Game - vCLOT

The goal of vCLOT is enable learners to identify the different artifacts required for blood clot formation and use them in a series of steps to complete the blood clot formation process. In order to play the game, the learner first signs in to the virtual world and creates his or her avatar. The learner is briefed about the blood clot formation process and what he or she is expected to do in order to win the game. This briefing is done with the help of a narration as shown in Fig. 1. The narration uses the audio/video player tool(that the Open Wonderland environment supports) and a flowchart to depict the procedural nature of the blood clot formation process.

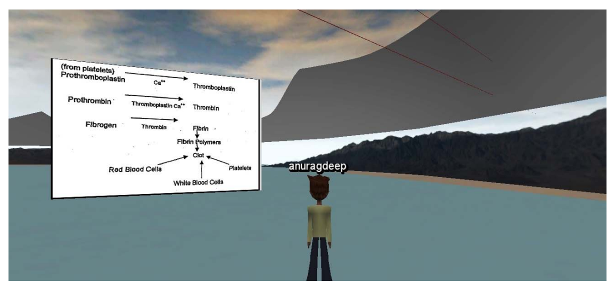

Figure 1: Sequence of steps describing blood clot formation in vCLOT

The learner then starts to play the game. The game is in the form of a quest. A quest is defined as a task involving multiple activities, that a player-controlled character must complete in order to gain a reward [10]. In vCLOT, the objective of the quest is to heal an injury by blood clot formation. There are a number of interactive artifacts floating and moving around the learner's avatar as shown in Fig. 2. Some of the artifacts in this quest are 'Prothrombin', 'Thromboplastin', 'Calcium ions', 'Fibrinogen', 'Fibrin threads', 'Platelets', 'White blood cells', and 'Red blood cells'. These artifacts correspond to the concepts that are involved in the blood clot formation process.

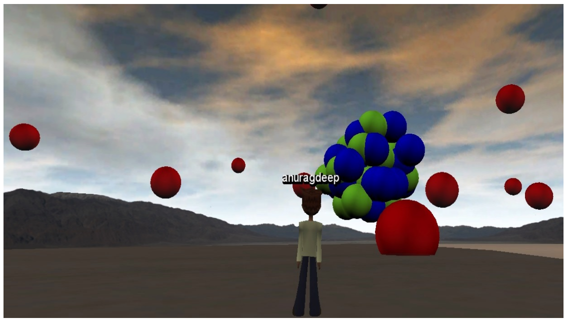

Figure 2: Blood components in vCLOT

In the blood clot formation process, the first step involves the combination of the protein Thromboplastin and Calcium ions to form Prothrombin. In order to perform this step in the virtual world, the learner travels around the virtual world, identifies and grabs the relevant artifacts(which are Thromboplastin and Calcium ions, in this step). Artifacts which are collected, are then synthesized to form a new artifact (which is Prothrombin in this step). "Grab" and "Synthesize" are user actions in the virtual world, done using the mouse. In a step by step manner, the learner has to grab and synthesize different concepts ultimately leading to blood clot formation. Successful blood clot formation heralds the completion of the quest. The whole game is a timed activity and the learner has to ensure that he or she advances through the different procedures as quickly as possible, so as to heal the injury. On successful completion of the game, based on the time taken, the number of right or wrong artifacts grabbed or procedure followed, the learner gets a corresponding trophy.

The above learning design is based on the principles of effective game design [6] and affordances of the virtual environment. In vCLOT, the learner has to grab and synthesize the correct artifacts in order to proceed further in the game. Proceeding further in the game ensures that the steps required for the formation of the blood clot are also learnt. Hence, the learning required to succeed in the game is the same learning required by the instructional objectives. The virtual world provides an immersive experience to the learner. While playing the game, the learner is making some executive decisions on inactive chemicals and triggers the corresponding activity. The learner is not only learning the process, but also plays an active part in its execution.

IV. THE DESIGN OF VCLOT

vCLOT has been designed in Open Wonderland which is an open source Java based toolkit to develop virtual 3D environments. Open Wonderland supports development of immersive learning environments where learners can become a part of their learning environment by assuming a role of an avatar and interact with artifacts available in the environment. The design of vCLOT can be broadly divided into three components, as seen in Fig 3: the frontend is the virtual world, the backend is a knowledge structure and the interface layer that facilitates communication and data processing between the frontend and the backend. The architecture diagram of the proposed virtual world game-based learning environment, vCLOT can be seen in Fig 3.

There are a plethora of tools that such an environment can include. Whiteboards, video/audio players, document viewers are a few such tools that are relevant in a virtual world meant for education. In addition to these existing tools, developers can import their own 3D or 2D models and define their behaviour. A game-based learning environment can therefore be made quite rich in terms of visual quality and possible interactivity. However, the interactivity has to be enabled with solid backend architecture support that facilitates exchange of information and execution of meaningful actions. This calls for some important design considerations that will facilitate seamless merging of operations between the front-end and the backend. vCLOT comprises the following components:

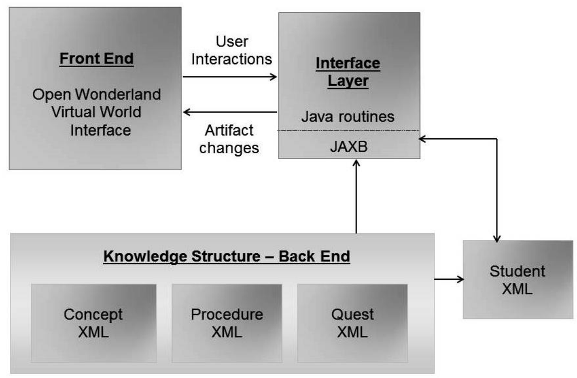

Figure 3: Architecture Diagram of vCLOT

1. Virtual World Component – This component is the user interface and includes all visible artifacts in the virtual world, their properties and possible interactions. For example, “Prothrombin” is an artifact which can be synthesized at one level or grabbed in a different level. On the other hand, "Calcium ions" are artifacts that can only be grabbed in the virtual world.

2. Interface Layer Component – The interface layer has various listeners for keyboard and mouse events that are triggered by the learner in the virtual world. For example, the learner can synthesize Prothrombin by selecting the Thromboplastin and Calcium ions artifacts and clicking on "synthesize" using the mouse. This mouse event is captured by the interface layer and a new artifact Prothrombin is created in the virtual world.

3. Knowledge Structure Component – The quests, concepts and procedures of blood clot formation are defined and stored in the form of knowledge structures. These knowledge structures are created and managed as XML files at the server. When a learner logs into vCLOT, these XML

files are read and converted to Java objects via the use of JAXB Java library. Based on the learner's interactions in the virtual world, vCLOT modifies corresponding objects accordingly. The modified objects are then transformed back to XML files and written back to the system.

The Knowledge Structure Component has the following three XMLs -

1. Concept XML - The function of blood clot involves multiple concepts. A concept is an idea about a class of objects, processes etc. Each artifact in the virtual world corresponds to a concept in the Concept XML. The collection of all relevant concepts along with their associations and relations with each other, are also stored. Fig. 4 shows the knowledge structure of concept “Blood” and its child concept “plasma” in XML.

```
<?xml version="1.0" encoding="UTF-8" standalone="true"?>
- <root>
  - <concept id="b_0">
      <name> Blood </name>
      <definition> Blood is fluid connective tissue </definition>
    - <hasSubConcept>
        <SubConcept id="b_1"> </SubConcept>
        <SubConcept id="b_2"> </SubConcept>
      </hasSubConcept>
    </concept>
  - <concept id="b_1">
      <name> plasma </name>
      <definition> Plasma is a part of Blood </definition>
    - <hasSubConcept>
        <SubConcept id="b_3"> </SubConcept>
        <SubConcept id="b_4"> </SubConcept>
        <SubConcept id="b_5"> </SubConcept>
      </hasSubConcept>
    </concept>
  </root>
```

Figure 4: Knowledge structure of concepts in XML

2. Procedure XML - Blood clotting process is accomplished by a sequence of activities wherein a given activity triggers a subsequent activity. Fig. 5 shows the knowledge structure of “Prothrombin creation” procedure in XML

```
<?xml version="1.0" encoding="UTF-8" standalone="true"?>
<procedures>
 - <procedure id="BC_1">
      <name> Prothrombin creation </name>
      <sequence_order> 1 </sequence_order>
      <definition> Prothrombin is created with the help of Thromboplastin and calcium ions </definit
    - <member_concepts>
            <!-- key concepts involved -->
        <concept id="b_19"> </concept>
        <concept id="b_7"> </concept>
        <concept id="b_20"> </concept>
      </member_concepts>
    - <questId>
        q_1
            <!--blood_clot-->
      </questId>
   </procedure>
 + <procedure id="BC_2">
 + <procedure id="BC_3">
 + <procedure id="BC_4">
</procedures>
```

Figure 5: Knowledge structure of a procedure in XML

3. Quest XML - Quest XML holds the information about the nature of interaction supported by the concepts. Structure of quest XML can be seen in Fig 6. Concepts in the form of artifacts, which can be grabbed, are labeled as clickable and concepts that are synthesized from other concepts are labeled synthesizable.

V. Usability Study Plan

Game-based learning in a virtual world environment for teaching learners procedural knowledge has at least two differences when compared to teaching and learning from textbooks or from observing an animation. It demands active involvement of a learners and it expects the learners to complete a task in the form of a game. Therefore it is important to evaluate the usability of the proposed virtual world game-based learning environment, vCLOT, before any further study can be planned. For the usability study, we plan to select a group of about 20 high school learners and allow them to play with the game. We plan to assess their perceptions towards the game via a questionnaire. This study will help us identify and fix key issues for further applying the game to classes and schools. Subsequently, we plan to establish the effectiveness of the game using a pre-test - game - post-test experiment on a larger group of learners.

```
<?xml version="1.0" encoding="UTF-8" standalone="true"?>
- <quests>
  - <quest id="q_1">
      <q_name> Blood clot </q_name>
      <maxScore> Clot_Trophey </maxScore>
    - <concepts>
      - <concept id="b_0">
          <isClickable>false</isClickable>
          <isSynthesizable>false</isSynthesizable>
        </concept>
      - <concept id="b_7">
          <isClickable>true</isClickable>
          <isSynthesizable>false</isSynthesizable>
        </concept>
      + <concept id="b_13">
      + <concept id="b_14">
      + <concept id="b_16">
      + <concept id="b_17">
      + <concept id="b_18">
      + <concept id="b_19">
      + <concept id="b_20">
      + <concept id="b_21">
      + <concept id="b_22">
      </concepts>
    </quest>
  </quests>
```

Figure 6: Knowledge structure of a quest in XML

In order to track learner's progress and performance, we plan to analyse the sequence of activities performed by them. The activities could be either collection and synthesis of right artifacts or collection of random wrong artifacts leading to no synthesis at a given procedural step.

VI. Conclusion

In this paper, we have presented the design of a virtual world game-based learning environment, vCLOT, to learn and apply knowledge about blood clot formation. vCLOT helps learners have a detailed conceptual understanding of blood clot formation in a fun and engaging environment.

This game enables learners to have an immersive experience of a physiological process leading to application of procedural knowledge. We expect vCLOT to motivate learners to identify the different steps in the procedural nature of blood clot formation. We plan to do a usability study focusing on sequence of activities performed by the learner in the game and collecting learner's perception about this system. Our future work also includes development of additional modules for other blood functionalities such as immunity, gas exchange, thermoregulation to name a few.

References

[1] R. C. Clark, "Developing technical training: A structured approach for developing classroom and computer-based instructional materials," John Wiley & Sons, 2011.

[2] Tactus Technologies, "V-Frog: Virtual frog dissection," Retrieved 02.05.16, from. http://www.tactustech.com/products/vfrog/documents/V-Frog-White-Paper.pdf, 2007.

[3] J. L. Schedlbauer, L. Nadolny, and J. Woolfrey, "Practising Conservation Biology in a Virtual Rainforest World," Journal of Biological Education, pp. 1-9, 2016.

[4] H. M. Huang, U. Rauch, and S. S. Liaw, "Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach," Computers & Education, vol. 55, pp. 1171–1182, 2010.

[5] S. A. Jin, "Leveraging avatars in 3D virtual environments (Second Life) for interactive learning: The moderating role of the behavioral activation system vs. behavioral inhibition system and the mediating role of enjoyment," Interactive Learning Environments, vol.19, no.5, pp.467–486, 2011.

[6] R. C. Clark, and R. E. Mayer, "E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning," John Wiley & Sons, chapter-15, 2011.

[7] Concord Consortium, "Geniverse," 2010.

[8] D. A. Jones, and M. Chang, "Pecunia-A Life Simulation Game for Finance Education," Research & Practice in Technology Enhanced Learning, vol. 9, issue 1, pp. 7-39, 2014.

[9] C. Lu, M. Chang, D. Kinshuk, E. Huang, and Chen, C. W. "Usability of context-aware mobile educational game," Knowledge Management & E-Learning: An International Journal (KM&EL), vol. 3, issue 3, pp. 448-477, 2011.

[10] G. Oh and J. Kim, "Effective Quest Design in MMORPG Environment," Game Developers Conference, March 11, 2005.