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Web-based Interactive Learning and Teaching of the Human Immune Response to Pathogenic Activity

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Abstract

The challenge of learning and teaching becomes evident when topics discussed are difficult to appreciate and understand, e.g. at the molecular level; and, the field of biology is replete with these. Hence, a good target for interactive learning object (ILO) development is how the immune system will respond to pathogenic activity. We demonstrated here the use of simulation to learn and teach the basics of the human immune response to pathogenic activity implemented as web-based ILO. Using SCORM [1], two ILO modules were developed, one each for bacteria and virus, respectively. Assessment of the ILOs by randomly selected high school and college students, and teachers, using the MERLOT [2-3] instrument to assess the accuracy of informational content and effectiveness as a teaching tool. In a scale from 1 to 5, evaluation results showed that the three groups of audience consistently rated the ILOs with mean ratings of around 4.5 across three subject criteria of MERLOT, namely: Quality of Content, Ease of Use, and Potential Effectiveness as a Learning Tool. This suggests that the ILOs rated well above "very good" (i.e. 4), and which means that it met the standards in multimedia educational resource for effective learning and teaching.

Keywords: interactive learning object, ICT-based learning, computer-based learning, web-based learning tool, human immune response, e-Learning, Central Philippines

Introduction

The field of biology is replete with topics that require innovative and explorative style of pedagogical approach for better appreciation and understanding as an alternative to the usual classroom instruction using traditional medium of packaged educational materials. The challenge of learning and teaching becomes evident when topics are discussed at the molecular level and presented in a manner that is difficult to appreciate and understand, and as such, is a good target for ILO development. A case in point is the human immune system, which is made up of special cells, proteins, tissues, and organs [4] that defend the person against germ and microorganism infections every day.

Brain [5] stated that there are at least two good reasons why human beings should even learn just the basics of their immune response. First, it is just plain fascinating to understand where things like fever, hives, inflammation, etc. come from when they happen inside one's body. Second, the immune system is usually part of the news when new drugs on the market are released. Hence, to better appreciate and understand thoroughly the news, one must have a basic understanding of how their immune system functions inside one's body.

In recent years, the application of computer technology to facilitate and enhance student learning and teaching in educational programs at all levels has been phenomenal especially in developed countries. For instance, research showed that the use of Information and Communication Technologies (ICT) can be an effective method for learning and teaching the concept of numbers and natural sciences phenomena at preschool level [6]. In fact, teaching through computers has a positive effect on learning since it is an interactive process, which possibly is the most important advantage of computer use in the teaching process against traditional classroom

instruction [7]. Furthermore, ICT offers virtually unlimited use of image, audio, animation, and video illustrations of biological phenomena in a cost-effective manner independent of time and place, which is a unique feature of the technology [8].

With the abovementioned considerations, any effort to explore and pursue alternative ways, particularly using ICT, to learn and teach the human immune response in a manner that will elicit the learner's interest for better appreciation of the topic and thereby promote understanding as well as motivate the learner to become actively involved in the learning process is a worthwhile undertaking.

One approach is through the use of a Learning Object (LO). A LO is a standards-compliant piece of e-Learning with an explicit objective and built-in assessment [9]. In the last decade, the idea of developing online courses using the LO approach has evolved based on its two practical functions: Reusability and Adaptability [10]. The former refers to the reuse in different learning environments of instructional web-based components while the latter means the individualization of instruction. Per the literature of pedagogy, the happy medium, or the average attentive span of a learner, is estimated to be between five and fifteen minutes of learning material [11].

An increasing relevant trend is the use of educational games, and simulation in learning environments [12]. In fact, this is pursued vigorously in other countries because of its power of engaging people. The users interact with other users in a fun way and with scenarios that involve problem solving, story and other engaging elements that enhance the learner's involvement, motivation and creativity, among other benefits.

On the other hand, simulation has its early roots in the 1930s with the emergence of Monte Carlo methods, which make use of suitable statistical sampling process in

resolving problems intractable by analytical methods [13]. Since then, simulation has been widely applied in many areas especially in health care. Simulation-based learning can help mitigate medical tension by developing health professional's knowledge, skills, and attitudes while protecting patients from unnecessary risks [14].

There are already numerous related immune system simulation programs. However, these simulations are more textual rather than pictorial; thus, it gives a less precise representation of the immune system components. Some of them also are not freely available.

For example, IMMSIM3, which is the newest version of ImmSim (Immune System Modeling and Simulation) and part of the Computational Immunology Research at Princeton University, U.S.A., basically, presents graphs, lines, and values of the immune cells. It shows how the number of immune system cells increase or decrease in relation to time and number of injected antigens. The whole model is represented as line and bar graphs showing cell distribution, cell population increase and trend.

In the previous work [15], which this study has built upon and is currently enhancing, the simulation is packaged as standalone software and runs in offline mode. In other words, the users need to have the simulation files copied to their computer's hard drive before they can view it as compared with accessing it in one location (e.g., an online server).

For this study, the goal is to demonstrate the use of simulation in learning and teaching the basics of the human immune response to pathogenic activity implemented as web-based ILO. To this end, two ILO modules were developed using the Sharable Content Object Reference Model (SCORM) [1] standard for each of the two most common types of pathogens, namely: bacteria and virus. The ILOs were assessed by different

groups of evaluators coming from random samples of the target audience of high school and college students as well as teachers (for both biology and non-biology majors) using the Multimedia Educational Resources for Learning and Online Teaching (MERLOT) [2-3] evaluation criteria in order to assess the accuracy of informational content and effectiveness as a teaching tool. Moreover, the developed ILOs strictly followed the 15-minute maximum runtime (per module); and, implemented a personal assessment feature (i.e. Quiz) in each learning module. Overall results indicated that the ILOs were rated approximately 4.5 on the average using the MERLOT rating scale from 1 (Unacceptable) to 5 (Excellent), which gives evidence that it met the standards in multimedia educational resource for effective learning and teaching.

Methodology

The study employed the Systems Development Life Cycle (SDLC) process in the overall software development effort. In addition, extensive data gathering and information retrieval activities pertaining to human immune system response, specifically on bacteria and virus intrusion, in conjunction with frequent content expert consultations throughout SDLC, were made to ensure the correctness of information presented. The choice to focus on bacteria and virus is primarily anchored on its importance as the two most common disease-causing pathogens in human, and also, most of the other disease-causing pathogens are strains of the two.

ILO Design

Each ILO module was designed using the SCORM standard. Basically, the simulation part was comprised of the following components, namely: the user interface (UI), the main window display seen by the user upon clicking the learning module; the control, which included the buttons and the graphical images that are used for (user)

interaction; and, the accompanying textual information that provided brief descriptions about the immune system cells and processes.

The UI was designed to be as easy for the user to navigate between scenes such as the use of navigation buttons ('Back' and 'Next') to offer user navigation freedom, and the 'Help' button to assist the user on what to do in order to continue to the next scene. On the other hand, graphical images such as shapes of cells and skin were rendered as close as possible resembling to color images found in Biology books used as references in this study. Moreover, pastel colors were used to avoid color distraction to the user. Adobe Flash and ActionScript application software were utilized in tandem creating the UI and controlling user interaction with the ILO. The choice of Flash was due to its instant access feature wherein users need only a web browser and Adobe Flash Player, which are already both installed on most computers [16]. Furthermore, Flash also provided an interactive environment for more involved multimedia experience [17]. For sounds and narration, the SayVoice text-to-speech software was used to form the audio narration files. Items from sound effects library were also used to enhance the user's learning experience when viewing the ILO.

To complete the module as LO, user assessment in the form of the quiz was implemented after viewing each learning module. The user has three levels of difficulty to choose: 'Easy', 'Moderate', and 'Difficult'; and upon selecting a difficulty level, the system generates randomly 10 questions from the quiz bank. In addition, the user is given 30 seconds per question to answer and could extend for another 30 seconds only. If the user fails to choose any answer after the allotted onetime extension, the system marks as wrong answer for that particular question. The amount of time (in seconds) of taking the quiz as well as the score is recorded by the system for each user's learning

session. Furthermore, the quiz bank can be updated anytime quite easily through the 'Administrator' function of the online delivery platform, CILOB [18], in which the ILO is tightly integrated using the MySQL database. Figure 1 shows the flow of data from the Flash file (i.e. ILO) to the MySQL database and vice-versa.

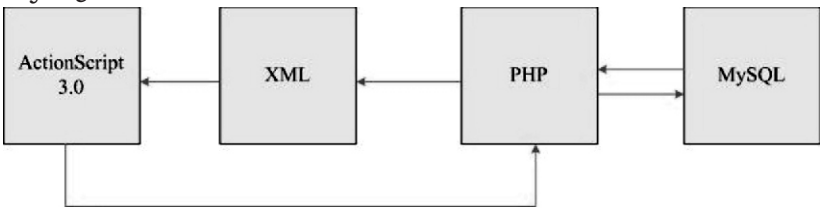

Figure 1. The illustration depicts a Data Flow Diagram of the ILO. MySQL database was used to store information such as passkey, quiz questions and user scores. XML and PHP were used to connect the Flash application software and the MySQL database.

ILO Deployment to Website

Since the ILOs were embedded in CILOB (Collection of Interactive Learning Objects in Biology) web application software, then there was no need to deploy it online separately. For as long as CILOB is up, the ILOs can be accessed and viewed online. However, the normal procedure to upload new ILO in CILOB is through the "Add ILO" function available only to the system administrator.

ILO Assessment

To determine whether the developed ILOs met standards in multimedia design for educational purposes, random samples from three groups of the target audience, namely: high school students, college students (BS Biology and non-BS Biology majors), and college teachers (teaching biology and non-biology courses), were identified and selected to evaluate the ILOs using the MERLOT

criteria as adapted from the MERLOT Module Review Form of Cochrane [16]. Three groups were considered to allow statistical test procedure to be applied for multiple group comparison, while further grouping within a group into biology and non-biology raters was done to determine if raters with prior knowledge in biology would have different perceptions/ratings of the developed ILOs than those without prior knowledge.

MERLOT evaluation criteria for peer reviews are one of the widely adapted evaluation standards for online digital learning and teaching materials. In fact, it is one of the most mature approaches in evaluating learning objects [19]. MERLOT's framework of evaluation criteria are based on 'Quality of Content', 'Ease of Use', and 'Potential Effectiveness as a Learning Tool', which were used to evaluate the developed ILOs; and, the ratings were assigned numerical scores from 1 (Unacceptable) to 5 (Excellent) for each question in the set under the criteria category. 'Quality of Content' criteria checked if the ILOs educationally present significant concepts, models, and skills for the specific topic, while 'Potential Effectiveness as a Learning Tool' criteria determined whether the ILOs are likely to improve learning and teaching given the ways faculty and students could use the tool. For the 'Ease of Use' criteria category, it only measured how easy for students and teachers to use the ILOs the first time. Overall learning object rating less than 3 is unacceptable [MERLOT (1997) in 19].

Furthermore, the assessment was done online (due to online viewing of the ILO) facilitated by Google Docs, where the form was posted and the instructions were sent to the respondents' email address and social networking sites.

Rating results were analyzed statistically using nonparametric statistical procedures to do away with the normality assumption of the data. For three-group comparison, Kruskal-Wallis H Test was applied, while that for between-group comparison, Wilcoxon-Mann/Whitney

Test was used, to detect statistically significant differences in the mean assessment scores between the different groups of raters.

Results and Discussion

The choice for the two most common pathogen types, bacteria and virus, in the simulation for learning and teaching the basics of the human immune response to pathogenic activity was based on its relative importance as disease-causing bacterial and viral infections, respectively, for some of the most common human illnesses. Hence, the target of ILO development in this study for better appreciation and understanding of the basic human immune response to pathogenic activity to would-be learners and interested individuals (for learning or teaching purposes).

Each ILO has the following technical properties: a) a dimension of 640 by 480 pixels (sample screen display as shown in Figure 2) and b) a frame rate of 30 frames per second (FPS). Property (a) takes into account for older computer systems that do not have a higher monitor resolution to allow it for viewing the ILO with minimal chances of display-related problems, or in other words, for backward compatibility purpose. Property (b) is the most common standard frame for "smooth" animation.

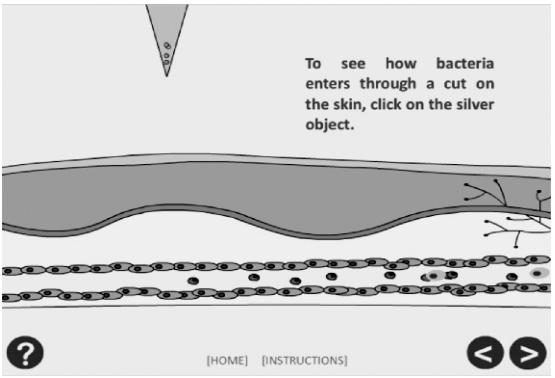

Figure 2. Screen display of the Bacteria ILO. This particular display would be shown once the Bacteria ILO menu item is clicked in the ILOs homepage. This part would also shows how the human antibodies interact with the bacteria pathogens to destroy it.

Figure 3 shows the usage block diagram of the ILOs. Whenever a user selects to view the ILOs for human immune response to pathogenic activity in the CILOB webpage, an 'Introduction' is played first prior to displaying the ILOs homepage. From here, the user can select to go either to the 'Bacteria ILO', the 'Virus ILO', or the 'Game'. Except for the 'Administrator' function, which is accessible only by the systems administrator through a separate log-in procedure, the other three (3) options are available to the public. Each ILO has an extension part, which can be viewed optionally and provides additional information via short animation of what will happen to the body cells and tissues when the bacteria (or virus) population reaches a certain threshold. This extension part serves as added learning in terms of portraying the implications of massive intrusions of bacteria or virus pathogens in the human body. After viewing the basic ILO, a quiz feature follows to assess whether the user learns from the session, which is a requirement to qualify as LO. There are three levels of difficulty of questions for the user to choose: 'Easy' which comes with hints while none for 'Moderate' and 'Difficult'. This feature allows gradual progress in the learning experience of the user with the ILO. Furthermore, to ensure that the ILO does not go beyond the 15-minute maximum runtime to coincide with the average attentive span of the learner [11], each question for the quiz is allotted 30 seconds, with a provision of a onetime extension for another 30 seconds. Another nice assessment feature of the ILO is its capability to record the user's score (after a particular learning session), viewing times, and per question answering duration by optionally supplying a username before starting a new learning session or taking the quiz again with a different level of difficulty since the user cannot retake the same level without viewing the ILO again. In addition, the system automatically remembers the last user who took the quiz such that if the same user views again the ILO, it can display the user's score summary,

which enables the user to monitor his learning progress. On the other hand, to avoid user's familiarity with the questions, the system randomly generates it from the quiz bank stored as a database. For the 'Game' option, this feature gives the user a 1-minute break in between learning sessions, primarily, to provide fun and enjoyment while accessing the ILO. However, the game is not an "ordinary" one considering that it simulates the start of phagocytosis process, in which the user simply plays the role of a macrophage and hit the bacteria and virus cells.

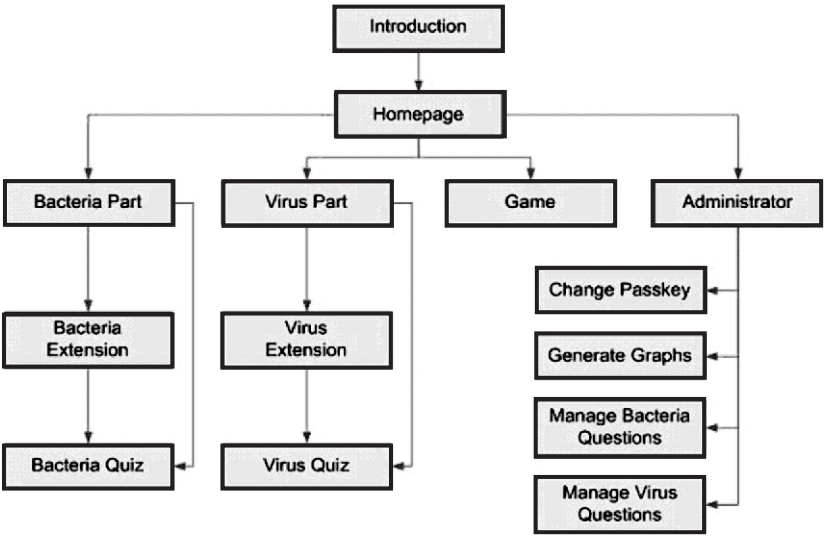

Figure 3. The usage scenario block diagram of the ILO. The directed arrows determine the logical flow in accessing the two ILO modules ('Bacteria' and 'Virus' parts) and the other two functions ('Game' and 'Administrator') connected through the ILOs' homepage, which serves as the main UI when selected in CILOB. The 'Administrator' function is inaccessible to the public user and use only for data management activities such as changing password of the systems administrator, updating of quiz questions in the quiz bank, and monitoring of ILOs' usage by means of graphs.

In terms of conforming to the SCORM standards, the ILOs were given a “Passed” rating for 'Accessibility', 'Interoperability', 'Durability', and 'Reusability' requirements. The 'Accessibility' requirement is met considering that the ILOs are available online, which make it easily reached in different or remote locations for as long as an Internet connection is present. For the 'Interoperability' requirement, the ILOs can be viewed in multiple browsers and multiple operating systems as well as the backward-compatibility with computer systems having old or low resolution monitor display. While that for the 'Durability' requirement, the ILOs were created using a software tool (i.e., Adobe Flash) that is widely-used in the industry [16], and therefore, easy to redesign or reconfigure by other developers. Lastly, for the 'Reusability' requirement, the ILOs as deployed (with CILOB) online could, therefore, be reused in various learning contexts many times.

Table 1 shows the mean ratings of the ILOs for 'Quality of Content', 'Ease of Use', and 'Potential Effectiveness as a Learning Tool' by respondent-raters grouped according to biology and non-biology majors. For the biology majors, the teacher group refers to faculty members who earned degrees in Biology or a related discipline and currently teaching Biology or Biology-related courses, while College student group, are those students currently enrolled in a Biology program and have taken already Biology or Biology-related courses. In the contrary, the non-biology majors are those groups of teacher and students who have not taken any Biology or biology-related courses, or in any way posses a degree in Biology or a related field.

Among the three groups of non-biology oriented respondents, the college students rated the highest with a grand mean (GM) at around 4.8 across the three subject criteria while the teachers rated the lowest (i.e. GM 4.3). Statistical test result revealed that a significant difference in the mean ratings is detected at 5% level of significance

(α = 0.05) with a p-value < 0.05. This implies that prospective users without prior knowledge in biology tend to have varied perceptions in viewing the ILOs in terms of 'Quality of Content', 'Ease of Use', and 'Potential Effectiveness as a Learning Tool'. However, on the average, they all agree that the ILOs met the standards in multimedia design as an educational resource by rating above 4.0, or equivalent to "Very Good (with minor issues to be resolved)" in the MERLOT rating scale. On the other hand, between biology-oriented respondents, no statistical difference is detected although it appears that there might be a noticeable difference in the mean ratings, but the evidence is weak. Still, the pattern is the same with college students' rating (GM 4.7) higher than teachers (GM 4.2) however the mean ratings are slightly lower this time than that of non-biology oriented respondents. This suggests that potential users with prior knowledge in biology unanimously view the ILOs as an acceptable multimedia educational resource as evidenced with a GM rating still above 4.0. Furthermore, the results suggest that teachers tend to rate conservatively than students, which implies that teachers, due to their teaching experience and depth of knowledge of the subject (especially in the case of biology majors), appeared "stricter" in assessing the developed-ILOs than students.

Overall, mean rating between non-biology (GM 4.6) and biology-oriented (GM 4.4) respondents is approximately 4.5 with the latter group seemingly conservative in rating the ILOs. Statistical test reveals no significant difference in the mean ratings between the two groups of respondents, which means they consistently rated the ILOs on the average. This further shows that the developed-ILOs can be useful in learning and teaching the basics of the human immune response to bacterial and viral pathogenic activities regardless whether the user has prior or has no prior knowledge in biology; and in which case, ensures that the ILOs can cater to a wider audience with varying degree of knowledge on the topics presented

without having to worry that their interaction with the developed-ILOs might be compromised.

Table 1. Mean ratings of the ILOs for 'Quality of Content', 'Ease of Use', and 'Potential Effectiveness as a Learning Tool' by respondent-raters grouped according to biology and non-biology majors.

CRITERIA CATEGORY	NON-BIOLOGY MAJORS*			GM	SD	BIOLOGY MAJORS^ns		GM	SD	OVERALL MEAN^ns
	ÇsA¨ ¼sn	College	High School			Teacher	College			
Quality of Content	4.30	4.80	4.60	**4.57**	0.25	4.20	4.70	**4.45**	0.35	**4.51**
Ease of Use	4.40	4.70	4.60	**4.57**	0.15	4.20	4.60	**4.40**	0.28	**4.48**
Potential Effectiveness as a Learning Tool	4.10	4.80	4.70	**4.53**	0.38	4.10	4.70	**4.40**	0.42	**4.47**
Grand Mean	**4.27**	**4.77**	**4.63**	**4.56**	0.26	**4.17**	**4.67**	**4.42**	0.35	**4.49**

Notes: GM - Grand Mean
SD - Standard Deviation
*p-value < χ∀ . ,. 3
ns - statistically not significant at χ ; . ,. 3

Conclusion

We successfully demonstrated the use of simulation in learning and teaching the basics of the human immune response to pathogenic activity implemented as web-based ILO. As a result, two (2) ILO modules, connected through its own homepage, were developed based on the SCORM standard with each for the two most common types of pathogens: bacteria and virus. The assessment results using the MERLOT evaluation criteria gave evidence that the ILOs are standards-compliant as multimedia educational resource for effective learning and teaching. Furthermore, users who have no prior knowledge in biology had different perceptions towards the ILOs as multimedia education resource, but consistently rated it above “Very Good” on the average, or the equivalent MERLOT rating of >4.0. Overall, the ILOs were “consistently” rated, regardless of which respondent group, with a GM of around 4.5 (out of 5.0 in the MERLOT rating scale) across three subject criteria, namely: 'Quality of Content', 'Ease of Use', and 'Potential Effectiveness as a

Learning Tool'. This lends support to claim that the ILOs possess the characteristics of accuracy and relevance, user-friendliness, and the potential as an effective learning tool, respectively.

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