Developing an Interactive Simulation Application for Undergraduate Biology Lab

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ABSTRACT

Undergraduate biology labs could be very expensive to run. This is because not only the experiment reagents and equipment are very expensive, but also more teaching assistants are needed for a typical undergraduate biology lab than other undergraduate labs. In this project an interactive simulation web application was developed to guide students in the lab to discover and solve problems by themselves, in a simulated-based learning environment. This app is aimed to be used in a real lab and increase both teaching and learning efficiency.

AUTHOR KEYWORDS

Undergraduate education; Biology lab; Simulation-based learning; Web application development.

INTRODUCTION

One common issue for undergraduate students is that some popular classes or labs are very hard to register because of limited capacity of those popular courses. One type of these popular course is undergraduate biology lab. The capacity of undergraduate biology lab is limited because they are usually very expensive to run, for the following two reasons: 1) the experiment reagents and equipment are very expensive, 2) more teaching assistants are needed for undergraduate biology lab. The reason for more teaching assistant are needed for undergraduate biology lab is that not only teaching assistants are needed to guide the students to design their experiments, but also help them to solve specific problems during their experiments. For example, for developmental biology lab, even if the student had read lab manual before coming to the lab, they usually will still have many questions about the experiment they are going to do. This is because in biology lab, the students always design unique experiments. When they are performing their customized experiments, they usually came up with specific questions which are not list on the lab manual, or it is not easy to find the answer online. Therefore, this resulted in a bottleneck to increase the teaching and learning efficiency.

To decrease the workload of teaching assistant in an undergraduate biology lab, one way is to have a very detailed lab manual to cover as many possible questions that student might have as possible. However, this approach will take more time to write the lab manual, which also increase the workload of teaching assistant. Moreover, the students would spend much more time reading the lab manual and might waste their time to read unrelated information to their own experiment.

Another solution is to apply simulated-based learning method in an undergraduate biology lab.

In this project, I developed an interactive simulation application to encourage the student to solve their questions by themselves. Simulation-based learning is a very efficient way for biology/medical education, my literature research showed that interactive simulation was applied and played a positive role in the following education areas: 1) medical imaging education (Aditya Dikshit, 2005), 2) leaning complex physiological models (Andreas Holzinger *, 2009), 3) education for nurse student (Neal F. Cooka, 2012), and 4) to teach spiritual and cultural aspects of palliative care to Interprofessional Students (Matthew S. Ellman, 2012). Furthermore, a research has shown that interactive simulation could help to develop system thinking skills (Evagorou, Korfiatis, & Nicolaou, 2009).

In my opinion the simulated-based learning is a better solution to decrease the workload of teaching assistant in biology lab, because:1) students are highly motivated because they are in charge of what they are learning; 2) students have the chance to explore or test their hypothesis, which can improve their critical thinking ability; 3) simulated-based learning provides an authentic learning environment, this would decrease the cost of education and increase the flexibility of education. Therefore, I developed a web application for simulation of sea urchin development, to guide the students to design experiment by themselves in a developmental biology lab.

METHODS

Gathering Requirement for the Web Application

The requirements for this interactive simulation application were gathered from the teaching assistant and undergraduate students from the developmental biology lab of University of Miami.

Design, Implementation and Test of the Application

The Class Diagram design is done using Lucidchart. ReactJS was used as the framework to implement the application. Manual test was done by myself and the students from the developmental biology lab to ensure the application has the desired function.

Deployment

The web application is deployed to AWS S3, it can be viewed and used by using the following URL: http://weiwuwayson.s3-website.us-east-2.amazonaws.com

RESULTS

Development Process

The whole development process lasts for 10 weeks (Figure 1). In the first three weeks, requirements were gathered, application class diagram and user interface were designed, and a low-fidelity prototype was made for millstone number 1. For week #4, week #5 and week # 6, I implemented the basic user interface and the function of the application, and have a functional application as milestone number 2. From week #7 to week #9, I refined the user interface of the application, did unit and system tests, and deployed it on AWS. For week #10, I wrote the paper and made the presentation for this project.

Requirement gathered for the Web Application

Based on the requirements gathered from the teaching assistant and the student, this web

application should be able to have the following three functions: a) The students could select different experiment set-ups in the interactive simulation application b) the students can get the recipe of the artificial sea water for the experiment set-up they selected c) Visualization of the sea urchin embryo development based on selected experiment parameters.

Class Diagram design (Figure 2)

The class diagram is shown in Figure 2. The DBSimulation class is the class to manage the behaviors of the application, including starting a simulation, resetting a simulation and calculating the recipe. The DBSimulation class includes variables needed to perform the above functions, including parameters needed for experiment set-up, imagesIndexes which decide which image to show in the front-end, and recipe information. The DBSimulation also includes utility functions such as simulating (calculating the imagesIndexes based on current experiment set-up), updating the parameters of the experiment set-up.

SetupPanel class is designed for students to enter their experiment parameters, including temperature, species, salinity, drug. SetupPanel can also update the corresponding parameters in the DBSimulation class.

SimulationPanel class stored the sea urchin embryo pictures at different stages. SimulaitonPanel has a function to show the right pictures at a certain development stage, based on the ImageIndexes variable from the DBSimulation class.

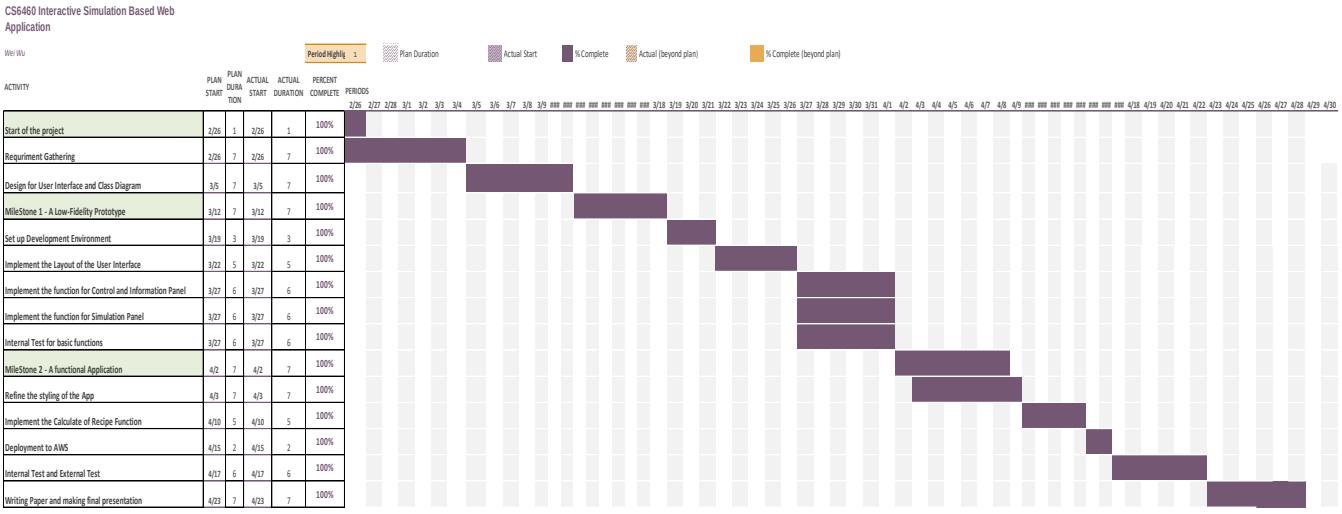

Figure 1. Gantt Chart for the Development Process

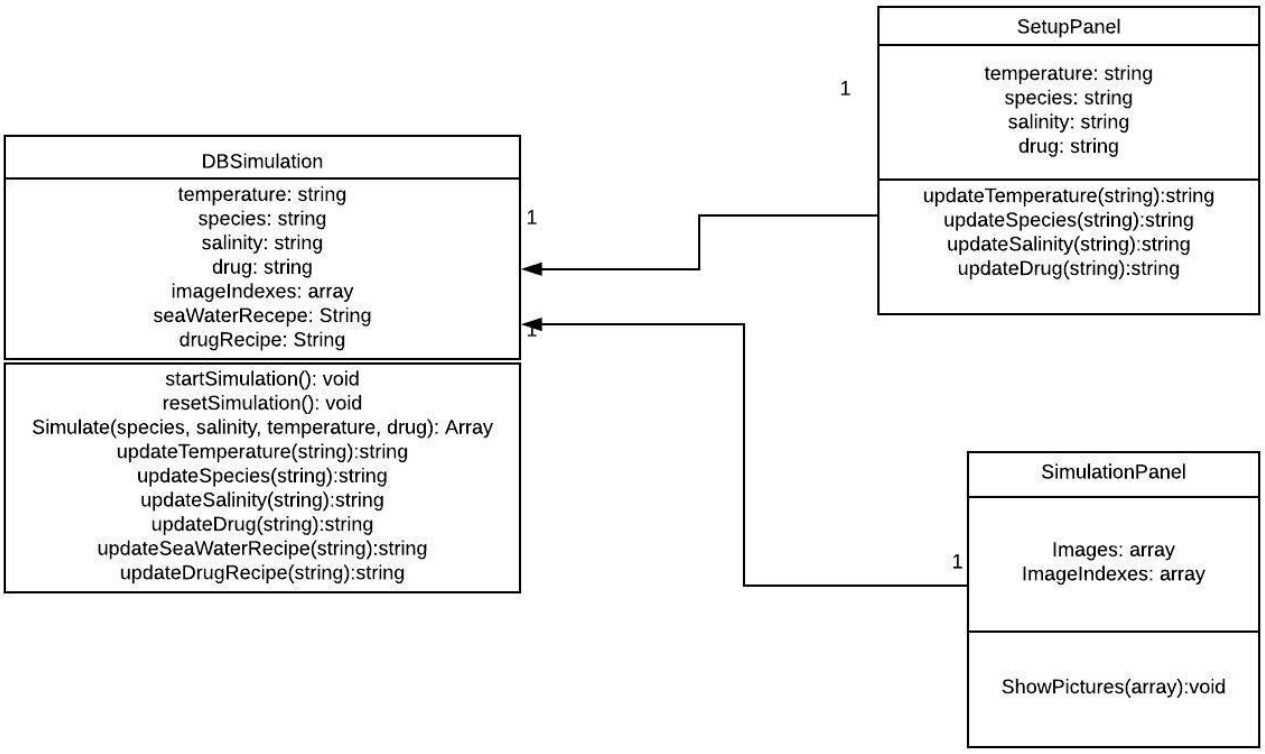

Figure 2. Class Diagram for the Interactive Simulation Web Application

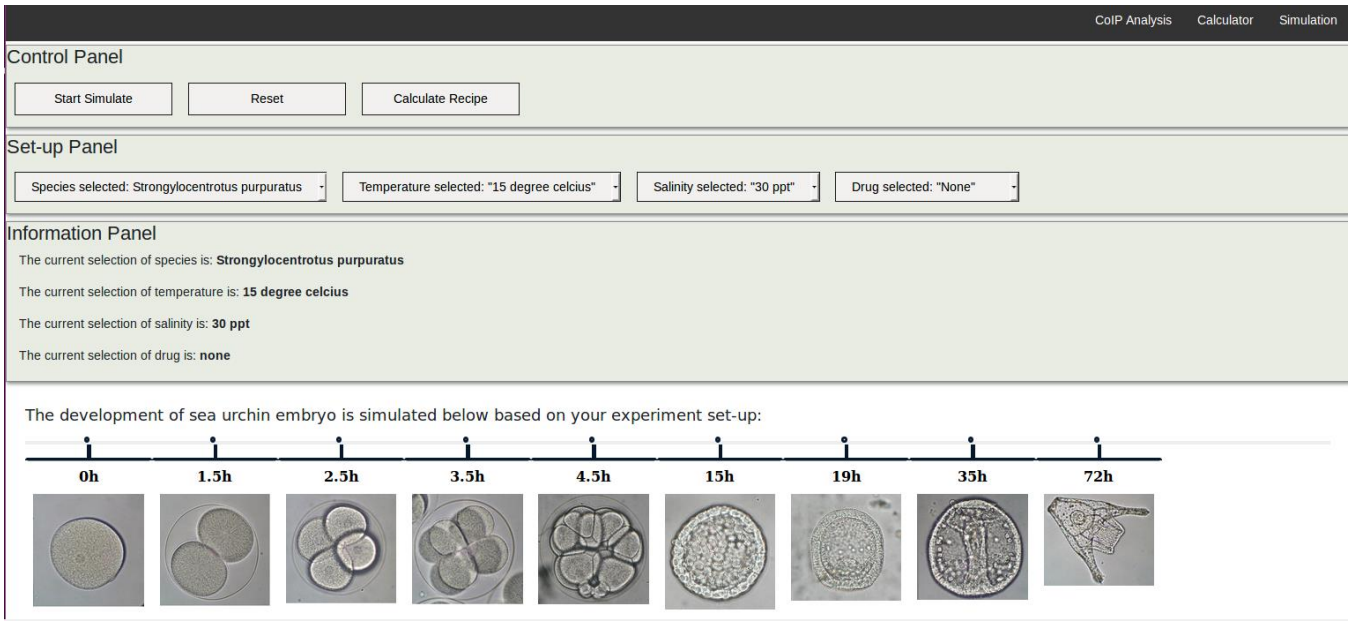

Figure 3. User Interface for this simulation web application

User Interface (Figure 2)

The User Interface includes four panels: control panel, set-up panel, information panel and simulation panel.

The user can control the behavior of the application in the control panel. The user can 1) start a simulation, 2) reset a simulation and 3) calculate the recipe for the artificial sea water of the simulation based on the current experiment set-up in the control panel.

The users can select the value of the parameters used in their simulation in the set-up panel, including temperature, salinity, species and drug.

The information panel would show the selected value for each parameter and would update the displayed value when a new value is selected.

The simulation panel simulates and shows how sea urchin embryo would look like at different development stages (hours after fertilization), based on the current experiment set-up.

User Manual

1) Before using this web application, please get familiar with the early sea urchin embryo development. For student in BIL150, please read through your lab manual. For other users, please refer to this link for more information: https://embryology.med.unsw.edu.au/embryology/index.php/Sea_Urchin_Development.

2) Think about what factors would affect the development of the sea urchin embryo. What would be your hypotheses?

3) Open a browser, go to the following URL: http://weiwuwayson.s3-website.us-east-2.amazonaws.com.

4) In the set-up panel, select the values you want to test for each parameter.

5) In the control panel, press "Start Simulation" button.

6) If your experiment set-up has been tried by another group of students, or can be found in the literatures, you will see the simulated development process in the simulation panel. Otherwise, you will get a response showing "there is not enough information form the literature, please design the experiment to test this experiment setup".

7) To get the recipe for the artificial sea water which you should use in your experiment, press "Calculate Recipe" button in the control panel. The recipe will show in a pop-up window.

8) To reset the simulation, press the "Reset" button in the control panel. All values will be reset to default values.

DISCUSSION

This web application for simulation of sea urchin embryo development not only allows the students to make predictions about their experiment, but also give them a quick way to find out the experiment set-up that haven't been tried before. Therefore, the time needed for students to design their experiment are expected to decrease in the lab. Furthermore, because this application also shows the students the exact development process for the sea urchin embryo, and give them the artificial sea water recipe, they would have less questions for the teaching assistant, therefore decrease the workload of the teach assistant.

This web application is implemented using ReactJS as framework. ReactJS provide a very efficient way to allow the web application to be highly dynamic and responsive to user input. In the future, this web application can also integrate the PhET framework (PhET interactive simulaiton, n.d.), which is a popular framework for interactive simulation, providing useful animation and graph libraries to make the application more interactive and interesting.

CONCLUSION

A web application was implemented based on the requirements based on the teaching assistant and students form an undergraduate developmental biology lab. This web application provides interactive simulation for the development process of sea urchin embryo based on the students' experiment set-up. The students can view real pictures of sea urchin embryo at each development stage based on their experiment set-up, and can get the artificial sea water recipe to perform their experiment. Both teaching and learning efficiency are expected to increase by using this web application in an undergraduate developmental biology lab.

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