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BiologAR: An Interactive Augmented Reality Application for Learning Biology in Secondary Schools in Malaysia

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Abstract— Biology is one of the subjects taught in secondary school in Malaysia. The subject requires a lot of visualization to enhance students understanding on the scientific theories they learned in Biology class. The advanced of Augmented Reality (AR) technology can be useful for students to help them understand Biology subject better as they able to visualize various scientific theories and concepts using 3D objects. AR also had been proven to be able to create a fun and interactive learning environment for these Generation Z students compared to traditional printed textbook. Accordingly, in this project, we are proposing BiologAR mobile application as an assisting tool to support teachers and students in teaching and learning Biology. This BiologAR application would help students to visualize some content of the Biology syllabus using AR technology. The application also provides a simple quiz for students to assess their understanding of the chapter. The application had been developed using Unity 3D software for Android platform. Based on the user testing conducted with the students and teacher, our BiologAR mobile application had been proven to be easy to use and useful to enhance students understanding of Biology subject.

Keywords— augmented reality, mobile application, biology, assisted learning environment, educational tools.

I. Introduction

In this paper we described the development of BiologAR, an e-learning mobile application that is integrated with augmented reality technology. The application is to be used as an assisting tool for Form 4 and Form 5 secondary school students to learn Biology. It is an interactive application that uses 3D visualizations, animations, sounds and graphics. The objective(s) of the development of BiologAR application are:

I. To help the student understand Biology subject better through visuals and explanations provided in the application.
II. As an assisting tool for teachers to teach and enhance their students understanding about Biology subject.
III. To expose students to use technology in learning, thus preparing them for the Industrial Revolution 4.0 (IR4.0) which emphasizes on the use of technology and internet in everyday life.

II. Problem Statement

A study by Weng et. al [1] found out that learning Biology from the textbook alone can be challenging to students as textbook is lacking in terms of interactivity and visualization –making the learning process less engaging and not effective. Similarly, another study by Sorgo [2] identified that some students have difficulties to visualize the Biology concept from information provided in the textbook due to lack of creativity. Besides, lack of exposure to AR-based e-learning technology also had been an issue as many students did not aware on how these applications would help them to understand the Biology subject better [3].

These problems hence motivated us to develop BiologAR mobile application, with the primary aim to enhance students understanding on Biology concepts through interactive 3D visualization using AR technology. By developing this BiologAR app, we believe students' interest, understanding and engagement in learning Biology subject would be improved.

III. Methodology

For the development approach, we are adopting the Iterative-Visual Cognitive Software Development Life Cycle Methodology (I-VC SDLC) by Chowdhury [4] as presented in the following Fig. 1.

This methodology was used because we as the developers need to understand how augmented reality works as a virtual model that appears and co-existing in the real environment through projection inside the application.

The methodology consists of four majour phases which are 1) analysis on the user needs and requirements, 2) design of the proposed solution, 3) development and evaluation of the mobile e-learning application, and finally 4) implementation and testing with target users. The subsequent sections in this article will be presented based on these sequential phases.

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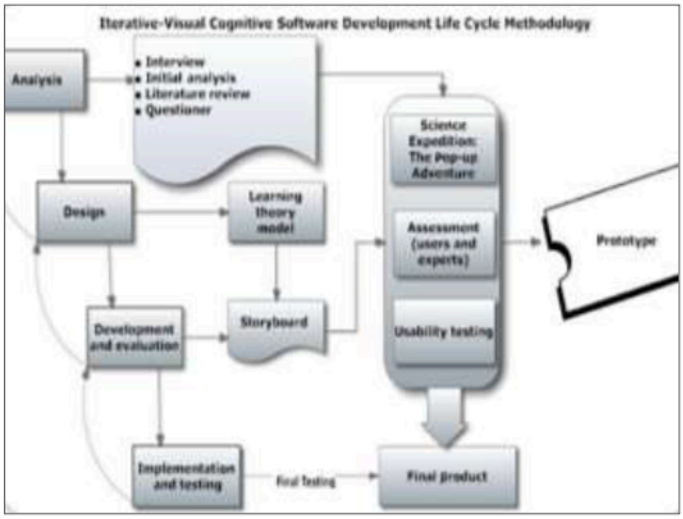

Fig. 1 Iterative-Visual Cognitive Software Development Life Cycle Methodology (I-VC SDLC) [4]

A. User Requirements Analysis

In order to understand the challenges that students experienced in learning Biology, a preliminary user study was conducted using survey method at two (2) secondary schools in southern Malaysia. Before we distribute our survey, we asked for approval to conduct data collection from both schools. Once approval had been granted, we proceed with the distribution of the survey to Form 4 and Form 5 students. A total of 95 students responded to our survey. The following Table I summarized the findings that we got from this user study.

TABLE I
SUMMARY OF FINDINGS FROM STUDENTS' QUESTIONNAIRE RESPONSES

Questionnaire Item	Students' responses (N= 95)
1. Do you find Biology subject difficult?	Not difficult at all (6%) Difficult (89%) Extremely difficult (5%)
2. Which kind of learning materials that you prefer to learn Biology?	Textbook (25%) Slides in class (38%) Notes from teacher (37%)
3. Does learning through textbook helps you to understand topics in Biology?	Yes (78%) No (22%)
4. Did you think that the explanation provided in the textbook sufficient for you to understand the subject?	Yes (44%) No (56%)
5. Do you think adding more visual explanations can improve your understanding in Biology subject?	Yes (100%) No (0%)
6. Which platform you normally used for e-Learning?	PC/Laptop (35%) Smartphone/tablet (42%) Never use (23%)
7. Which feature is the most important to include in the eLearning application?	Visual 3D model (53%) Video explanation (30%) Exercises (17%)

Based on Table 1 above, in terms of level of difficulty, majority of the students feel that Biology is difficult (89%) and extremely difficult (5%) subject. Only very few students (6%) think that the subject is relatively easy. In terms of learning materials preferred to learn Biology, many of the students prefer to use slides in class (38%) and notes from teachers (37%) compared to those prefer to use textbook (25%). However, when we asked them if the textbook helps them to understand, majority of the students said yes (78%), while only (22%) said otherwise.

Besides, when we asked the students if the explanation in the textbook is sufficient, the result shows that more than half of the students (56%) did not agree to the fact that the textbook has been giving good explanations for them to better understand the subject. We believed this is because the information and explanations provided by the textbook are lengthy and complicated. Besides, we also found out that they are having difficulties trying to understand some topics in Biology where they need to visualize those scientific concepts.

Regarding the idea on adding more visual explanations to enhance understanding on Biology subject, it is evidence that all students (100%) agreed that the approach could potentially improve their understanding. This indicate that it is apparent that students need some visualization assistance to understand some topics in the Biology subject better.

Apart of asking questions on their thought on learning Biology, we also asked them on their technological experience to know about the platform that they are familiar with for e-learning. The result shows that 42% of the students use smartphones or tablet compared to 35% using personal computer/laptop. This is potentially due to the fact that smartphones and tablet are more accessible and portable which makes them easier to use for e-learning anytime and anywhere [5]. Besides, we also asked students on the most important feature to include in the e-learning application, to which more than half of the students (53%) suggested visual 3D as the most important feature, followed by video explanation (30%) and exercises (17%).

Further, we also asked the students on topic(s) in Biology subject that they found difficult to understand (*they may choose more than one topic for this question*). The result is presented in the Figure 2.

Based on the table. it is apparent that the 'Cell Division' became the most difficult topic with a total of 65 out of 95 students (68.4%) think they need more guidance for it. This outcome helps us to decide that 'Cell Division' as the most important chapter that need to supported with 3D AR visualization in our BiologAR app.

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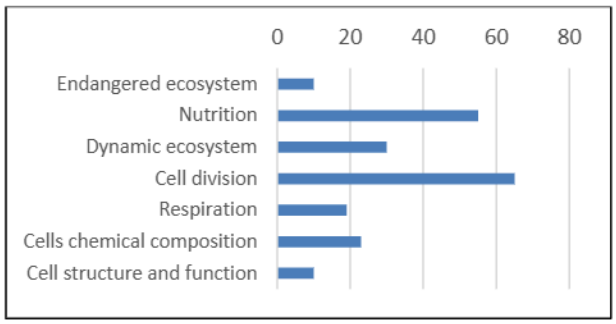

Fig 2: Chapters in Biology That Students Found Challenging to Understand (N=95)

B. *Content Development and Storyboard*

When developing and designing the application, we as the developers need to consider several aspects; which include the syllabus of the subject and topics for the content. Thus, in the early stages of the project, we have conducted multiple discussions with Biology teachers at school to make sure that the theoretical concepts presented in the application along with the accompanied 3D visualization are valid, accurate and able to strengthen students' understanding.

Apart of discussions and advices from the teacher, we also use Biology textbook adopted at the school as our main reference. One of the modules in BiologAR is the cell divisions topic which made up of six (6) phases –interphase, prophase, metaphase, anaphase, telophase and cytokinesis. All these 6 phases have different processes. Therefore, six (6) different 3D models with six (6) different animations are required to be developed to help students easily visualized the cell division processes and profoundly understand this topic.

Further, we also developed storyboard. Storyboarding is a very crucial phase in AR development to give a clear view on the flow of the application, the contexts of use and the system interfaces [6]. The following Fig. 3 shows some storyboard developed for BiologyAR mobile application.

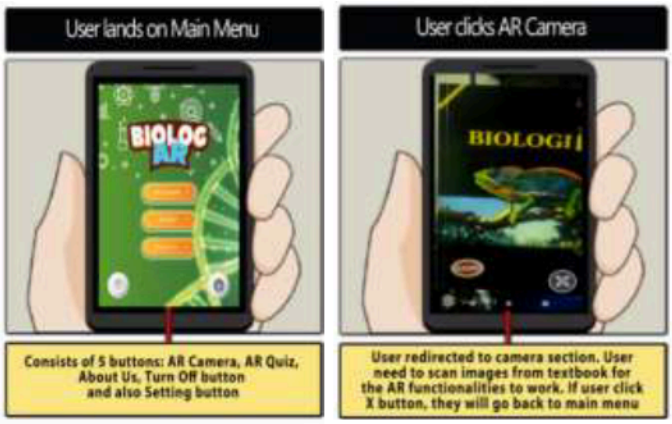

Fig. 3 *Storyboard of BiologAR*

C. *Mobile Application Development*

Project development is a very crucial process in developing any kind of application because this phase would determine the success of the end product. In order to develop BiologAR mobile application, we as the developers need to have a thorough and organized plans, which includes considering several issues such as availability, accessibility, integration, and compatibility of the features and content. This is because some features are compatible with different software and can be integrated into one another, while some are not.

In this project, the development process involves both front-end and back-end processes where the front-end consists of the user interface and illustration, digitizing 2D/3D art and scenes. While the back-end process consists of configuration, authoring and coding.

For front-end, we used a few tools to develop some of the components and media for the application which includes Adobe Illustrator and Adobe Photoshop for some illustration and user interface. For back-end coding, we use Unity3D for 3D Model development and Vuforia for AR technology and development.

1) Digitizing 2D/3D Art

The background, illustrations, 2D sprite or models for the user interface were done using software such as *Adobe Photoshop* and *Adobe Illustrator (see Fig. 4)*.

Fig. 4 Designing 2D user interface in Photoshop 2020

As for 3D models and animation, they were done by using *Blender* software. Fig. 5 below shows example of 3D modelling in *Blender 2.8*. As digitizing 2D and 3D art was done in different software, the format for the end product is different from one another. Thus, we exported the raw files into the same format for ease of use.

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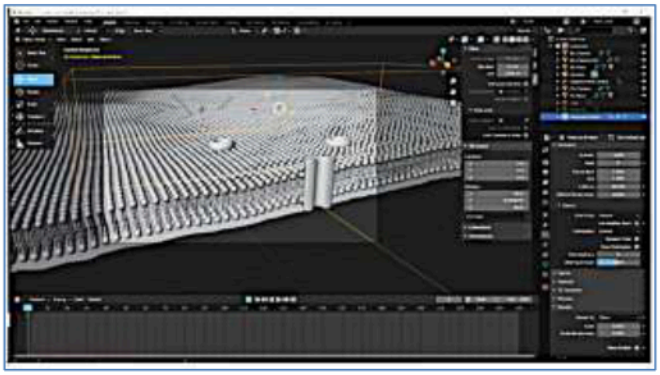


Fig. 5 *3D Modelling in Blender 2.8*

2) *Digitizing Scenes*

Apart of 2D and 3D digitization, the front-end process also includes digitizing scenes. The scenes include the main screen, selection screen, controller, and camera user interface. The process to create every scene according to the storyboard was done using *Unity 2020* software (*see Fig. 6*).

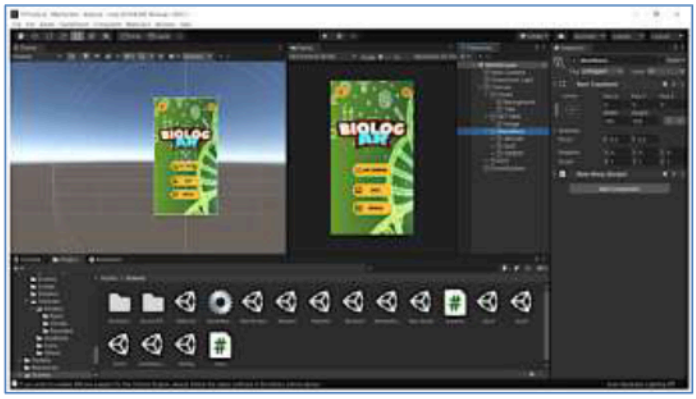


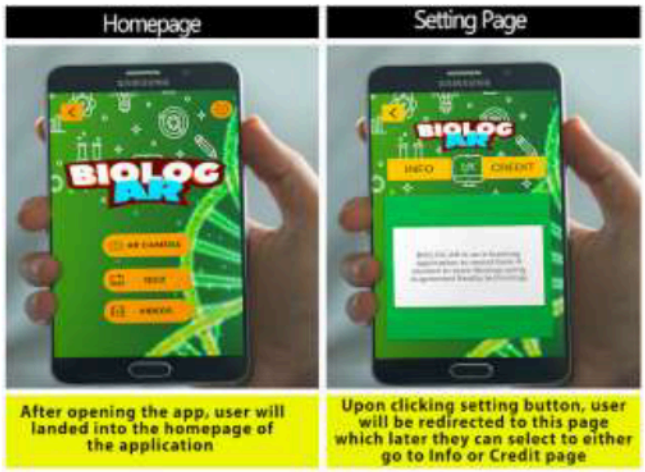
Fig. 6 *Software development in Unity 2020*

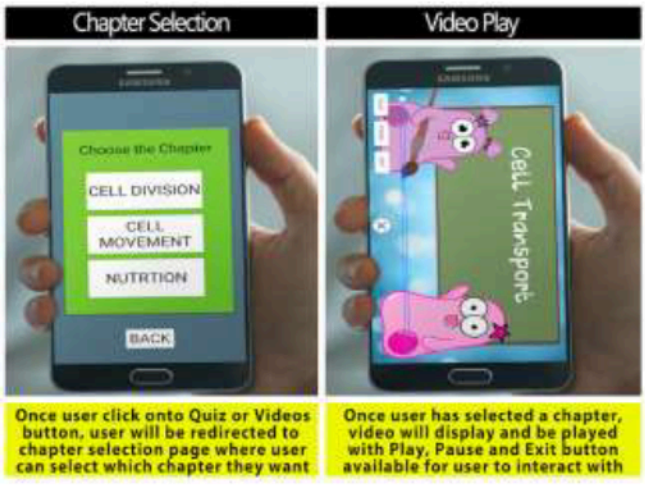
3) *Authoring*

In the later stages, the back-end development was done where some implementations and coding were programmed and tested. Rapid testing was done during the development to handle some errors and bugs. At this stage, the user interfaces already have their own programmable functions. Each function was tested before we moved into further development. We tested the functionalities of the product to detect any issues or problems before we deploy the real end product.

D. Implementation

Once the application has been completed, we have decided to deploy the end product on Android platform and upload it on the Google Playstore for commercial use. However, since the BiologAR have not reach commercialization level yet at the moment, we choose to share the Android Application Package (APK) using Google Drive. This APK can be installed on most Android smartphones that use Android 4.4 or Android 'KitKat' and higher. The following Fig.7 shows the users interfaces (UIs) of the BiologAR mobile application after the development have been completed.





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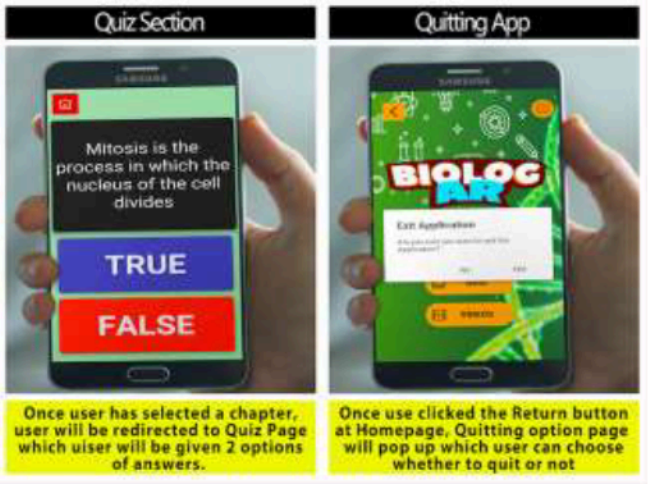

Fig. 7 *The user interfaces (UIs) of BiologAR application*

E. Usability Testing Session

It is very important to conduct usability testing of the BiologAR application with end users (students and teachers) to evaluate whether the application is easy and effective to use as assisting tool for learning Biology. Besides, it would also inform the developers on potential improvement that could be made to enhance the functionality and usage of the application.

For this purpose, we have conducted a series of Usability Testing session swith five (5) participants comprising of four Form 4 students who are studying Biology and one teacher teaching Biology subject to evaluate the usability of our BiologAR mobile application. Although the number of participants in this study is few, but according to Nielsen [14], a minimum of five participants is already sufficient to identify 85% of usability problems.

In the beginning of the usability testing session, participants were asked to fill up a set of questions asking about their demographic details. Then, a list of tasks was given to participants in order to ensure they interact with each feature of BiologAR. A total of nine tasks were given to participants to complete which are; 1) navigate through the application, 2) run the augmented reality camera, 3) answer the quiz, 4) play and watch the video, 5) display the 3D model in AR environment, 6) control the video (play, pause, exit), 7) go back to the recent page, 8) exit the application, and 9) control and move the 3D model in AR environment. After the participant completed all the tasks, a post-test usability testing questionnaire were administered to get participants feedback on each feature of BiologAR they interact with.

IV. RESULTS AND DISCUSSIONS

The following Table 2 summarized the participants' feedback as they interact and completed the given tasks on BiologAR mobile application.

TABLE II
PARTICIPANTS FEEB ON BIOLOG.AR FEATURES

Tasks	User Feedback
1. App navigation	*P1:* Everything displayed on the apps are simple, I had no problem going through the apps.
	P2: No problem to navigate
	P3: I can navigate through the application
	P4: Easy to understand the navigation
2. Run the augmented reality camera	*P1:* The camera works fine with the 3D models displayed in it
	P2: Can run the camera
	P3: The camera is working
	P4: Camera is okay
3. Answer the quiz	*P1:* Questions provided are suitable for students, not too easy and not too hard
	P2: The sound produced when answering the quiz makes the quiz more interesting.
	P3: The quiz does not have scores. Maybe having scoring feature will make it more interesting.
	P4: Only true or false quizzes available. Multiple choice quizzes can make it harder.
4. Play and watch the video	*P1:* The video can be played with no problem.
	P2: I can play the video with no problem.
	P3: I can open the video.
	P4: The video is playable.
5. Display 3D model in AR environment	*P1:* All 3D models are designed similar towards the actual model which is pretty impressive.
	P2: Every 3D models inside the apps can be viewed after I scanned the picture.
	P3: The AR can only be displayed if the camera is directed to the image. It is gone if the camera is not directed to the image.
	P4: The 3D model can be displayed. Some audio explanation or marker on the model could help.
6. Control the video (play, pause, exit)	*P1:* I can play, pause and stop the video easily as they are buttons which allow me to do so.
	P2: This feature is really helpful to watch videos
	P3: The control is not that smooth. No time frame displayed.
	P4: The video can be played. Only playtime not displayed.
7. Go back to the recent page	*P1:* The back button is really handy to be used to return to the previous page.
	P2: Back button looking simple, easy for me to recognize what it is for
	P3: I can go back and forth on any page
	P4: Easy, very straightforward.
8. Exit the application	*P1:* No problem exiting the apps.
	P2: I can exit with no problem
	P3: I can exit the application
	P4: Can exit using the app exit button only, cannot exit using phone back button.
9. Control and move the model in AR environment	*P1:* I can interact with the 3D models
	P2: I can zoom in and zoom out the 3D models
	P3: The 3D model can only be scaled up and down. The animation cannot be controlled.
	P4: 3D model can be moved around and scaled but only on the image plane.

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Besides that, we also asked the participants to give score from 1 (poor) to 5 (excellent) in terms of ease of use, attractiveness of the user interface, ease of navigation, user friendliness, content of the application, and overall satisfaction. The result is summarized in the following Table III.

TABLE III
AVERAGE SCORE GIVEN BY THE PARTICIPANTS

Criteria	Score (average)
Ease of use	4.5
Attractiveness of the UI	4.0
Ease of navigation	4.75
User friendly	4.25
Content of the application	3.75
Overall satisfaction	4.5

Based on the above Table III, participants rated 'ease of navigation' with the highest average score of 4.75 indicating our BiologAR is indeed easy to navigate. In addition, in terms of 'ease of use', 'attractiveness' and 'user friendly', a satisfactory average score of 4.5, 4.0 and 4.25 respectively, also had been received.

However, although the participants gave an average score of 4.5 for 'overall satisfaction', in terms of the content of the application, participants gave slightly lower average score with only 3.75. The participants further suggested to improve the app with more attractive and sleek user interface design.

The importance of usability, ease of navigation, attractiveness, and good user interface design in AR applications have been consistently highlighted in several previous studies. Kim et al. [7] for example emphasize that AR applications need to be intuitive and straightforward to ensure that users can quickly learn and operate them without confusion. Research has shown that factors such as learnability and simplicity are critical for user engagement and satisfaction.

A recent study by Nikou [8] similarly found that if students find the AR tools intuitive and user-friendly, they are more likely to engage with the technology and benefit from its educational potential.

In terms of ease of navigation, Santos et al. [9] emphasize that efficient navigation is very crucial for users to move through the AR environment seamlessly, as any issues such as the arrangement of on-screen markers and clarity of visual cues can significantly impact the user experience. Additionally, AR applications that incorporate immersive and interactive design elements not only enhance learning outcomes but also increase student motivation, engagement, and curiosity, which are crucial for effective learning process [10].

Attractiveness of the AR application user interfaces also plays a crucial role in enhancing user engagement – particularly for students. Aesthetic elements such as color schemes, layout design, and graphical components must be carefully designed to enhance the overall user experience [7]. In fact, a study by Sathyapriya [11] found out there is a need for AR applications to be attractive to sustain student interest and improve understanding. Besides, an AR application that can transform traditional learning also must be interactive and engaging, to sustain student motivation and retention.

Further, our usability testing participants also give several suggestions on how BiologAR could be improved. First, the 3D models could use some labeling and animation with audio explanation. According to Billinghurst et al. [12], the inclusion of labels, animations, and audio explanations in AR applications will enhance the user experience by making complex 3D models more understandable and engaging.

Besides, our participants also suggest the BiologAR interfaces to be more intuitive. A systematic review by Ibanez and Delgado-Kloos [13] highlighted that the intuitiveness is indeed a critical factor for the successful adoption and effectiveness of AR in educational settings, as students should be able to focus on the content rather than struggling with the technology.

V. CONCLUSIONS

Students are having problems in understanding the Biology subject from the textbook alone because the textbook lacks of interactivity and visualization. Our BiologAR mobile application attempt to overcome this problem by visualizing some topics in the Biology syllabus using AR technology and 3D visualizations. The results show that participants found BiologAR mobile application to be easy to use, easy to navigate, user friendly and useful as assisting tool for learning Biology. However, some areas need to improve such as enhancing the 3D model figures, improving the attractiveness of the user interfaces, adding more interactive features in the quiz feature and include more contents in the future.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest

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