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Designing Prototype Laryngo-App Using 3D Animation in Anatomy of Larynx

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Abstract: Learning about the larynx is difficult for healthcare professional students. The students need to visualize laryngeal structures and understand its function for further use in clinical application. The current traditional learning approach is not considered the most effective considering its limitations with learning resources, such as 2D images, cadaver, and physical models. This research proposed a prototype of a mobile learning application, called Laryngo-App with a 3D larynx model and animation to promote student's self-learning. The prototype was approved by experts before further being used in anatomy learning. The results from expert feedback revealed moderately high satisfaction. A prototype was divided into four parts. First, the larynx content was suitable for self-learning. Second, the larynx 3D model was appealing and could accurately represent its structures. Third, 3D animation illustrated the obvious movements. Lastly, the quiz questions were suggested for the improvement in terms of the level of difficulty. To summarize, our proposed prototype of Laryngo-App is appropriate to be an interactive learning material for students. Moreover, the prototype could be developed to be an application that allows students to learn independently from anywhere and anytime.

Keywords: Anatomy learning, Larynx, mobile learning, 3D Model, Laryngo-App

1. Introduction

Anatomy is an essential science for healthcare professional education as a critical and fundamental knowledge for clinical practice. Learning anatomy requires 3D visualization of shape, location, and organization of the organs to effectively understand the relations and functions of the structures in the human body. For junior medical and healthcare professional students, some lessons are complicated and difficult to understand. Additionally, the dissection in some small and deep parts of the body require experience and advanced dissection skills. A larynx is one of those structures. This crucial organ allows humans to be able to verbally communicate with others, normally breath, and switch the routes for air to pass through the trachea and for food to enter the pharynx. The students need to understand anatomy of the larynx, including its functions to enable further clinical application. Learning about larynx always challenges the students because the larynx is small and complex. Cadaver dissection without damage to some parts of the larynx is difficult for inexperienced students, resulting in limitation of 3D visualization. Moreover, explaining about the functions of the larynx, including mechanism of vocal cord movements with two-dimension pictures and cadaver specimens is scarcely understood. Aslo, the physical rigid larynx model cannot effectively demonstrate the movements. The students also struggle with self-learning. Therefore, learning tools that can help students to visualize the laryngeal structures and understand the mechanism of its functions is needed. There are several learning tools used in learning anatomy, including 3D computer models and 3D animation. The 3D model and animation have been widely applied in teaching anatomy for more than a decade to enhance understanding about spatial relationships and enable mental imagination of human structures. The review article (Azer & Azer, 2016) reported that 3D computer models were delivered to the students via various platforms, for example, web-based, computer-based and mobile-based. There were many previous study results regarding its effectiveness, mainly divided into two aspects, student's learning outcomes and satisfaction. Triepels et al. (2020) reviewed the effectiveness of using 3D learning tools on student's learning outcomes, compared to traditional learning methods was reported in both ways. Some studies

showed a significant improvement in the outcomes whereas some reported insignificant differences. Noticeably, the results might be varied due to topics of anatomical content, design of the study, and numbers of participants. However, their team concluded that using 3D visualization was a more effective method compared to the traditional ones. The results of other studies suggested that 3D anatomical models were more efficient than studying from textbook alone (Battulga et al., 2012), and learning with 3D models led to a better understanding of shape and relationship among the anatomical structures (Sonia et al., 2016). For the student's satisfaction, it was explored both qualitatively and quantitatively. Most of the studies reported positive feedback from the students. The student's feedback in the study of Sonia et al. (2016) revealed the 3D models enhanced the understanding of anatomical structures and their relationships, gave the students more opportunity to review the lesson, and was interesting due to its novelty. The study of Tan et al. (2012) reported that students preferred learning with 3D models. Some students suggested the lecturers to use it as a supplement for the lesson (Hu et al., 2009). Beside the 3D models, the study of Hoyek et al. (2014) suggested that 3D animations used in teaching anatomy enhanced spatial ability and capacity of structure imagination, facilitated visualization and helped students in forming a clearer mental representation of the structures.

The 3D models and animation are also known as 3D visualization. The 3D visualization refers to graphical content created by 3D software. It is implemented in many industries to generate content including images, diagrams, and animations to deliver a better understanding of communication. The 3D visualization can be used in education, teaching and learning in many fields. In the medical education field. There are several technologies or tools that can help students learn anatomy such as virtual reality (VR), augmented reality (AR), 3D computer model, and 3D animation. In 2009, Petersson et al. had experimented on a new VR technique for anatomy learning based on virtual contrast injection using the 3D visualization method as a learning tool. The results showed the student's attitude towards the positive in learning compared with anatomy textbooks. The results were not the same with dissections, however, the experiment had a beneficial effect on learning. (Petersson, 2009). Also, the concept of the Mobile Learning Method was introduced by Alan Kay in the 1970s and he formed a team to develop a "Dynabook" and aimed for children to access the digital world using a portable and hands-on personal computer. (Maxwell, John (2006). Tracing the Dynabook: A Study of Technocultural Transformations.) In 2018, Kurniawan, M. H., & Witjaksono created a mobile learning application using Augmented Reality technology for Human Anatomy learning. Using 3D human anatomy provided students with an understanding of human anatomy visualization. (Kurniawan, M. H., & Witjaksono, 2018).

Focusing on the 3D visualization of the larynx, the 3D computer model of larynx created by reconstruction of MRI and CT image with the imaging software was first established in 1998 (Rubin et al., 1998). This method gave a realistic character for the model. Later, the larynx 3D model was created by the same methods and used in teaching anatomy via web-based platforms (Fritz et al. 2011; Hu et al. 2009; Tan et al. 2012). The results of studies showed that learning with the 3D larynx model tended to improve the test score, compared to learning with the 2D image (Tan et al., 2012) and to promote long-term retention of the knowledge (Fritz et al., 2011).

This information has proved that 3D visualization has become an interesting and beneficial tool for teaching and learning anatomy. It should be considered as an alternative learning tool that can help students learn more effectively. Moreover, it would support the needs of the students as an additional learning tool which assists them in self-lesson review and promotes self-learning. Despite the fact that 3D models of the larynx have been widely used, no study mentions 3D animation that demonstrates functions of intrinsic muscles of the larynx and movements of the vocal cords. Therefore, the intention of this study is to develop a prototype of the mobile learning application, called 'Laryngo- App', which consists of the 3D computer models and 3D animation of the larynx, demonstrating actions of intrinsic muscles of the larynx which control the vocal cord movements during respiration and phonation.

2. Research Approach

The Larynx-App aimed to be implemented for teaching and learning in Anatomy for second year medical and dental students at Mae Fah Luang University, Thailand. This paper reported the first step of

developing the application, a prototype creation. There are two processes in preparing this prototype: Theoretical approach and Mobile Application Design Process

2.1 Theoretical approach

2.1.1 Application Requirement

In Mae Fah Luang University, the larynx is considered an essential topic for medical and dental students. Currently, the lesson is routinely based on lecture and cadaver dissection which are usually limited by time. Anatomy lecturers use a cadaver larynx specimen (figure 1.a)) to demonstrate real laryngeal structure. Unfortunately, its structures are hardly identified and mostly destroyed during removal from the body. One of the lecturers has tried to build a moveable physical model (figure 1.b)) for explaining its functions. Still, only one model is not enough for every student and unable for students to personally use out of the class. The students have to review the larynx topic by themselves in order to complete the exam and gain comprehensive understanding for further use in clinical application. It was frequently mentioned as a difficult topic in the course evaluations. To improve teaching and learning processes of the course, the lecturers have considered helping the students in their self-learning in every possible way. The 3D visualization and mobile application were brought up to discuss the possibility to use as an option for this issue. They concluded that the students should receive additional learning tools apart from the traditional learning resources. Therefore, the Laryngo-App was initiated to create a learning tool to assist the students in self-learning. The compartments and functions required in the application are;

1.Providing a summary of knowledge about the larynx.
2.Using 3D models to demonstrate the musculoskeletal structures of the larynx.
3.Using 3D animation to demonstrate the functions of intrinsic laryngeal muscles and movements of the vocal cords.
4.Giving opportunities for the students to take a quiz for self-development in learning.

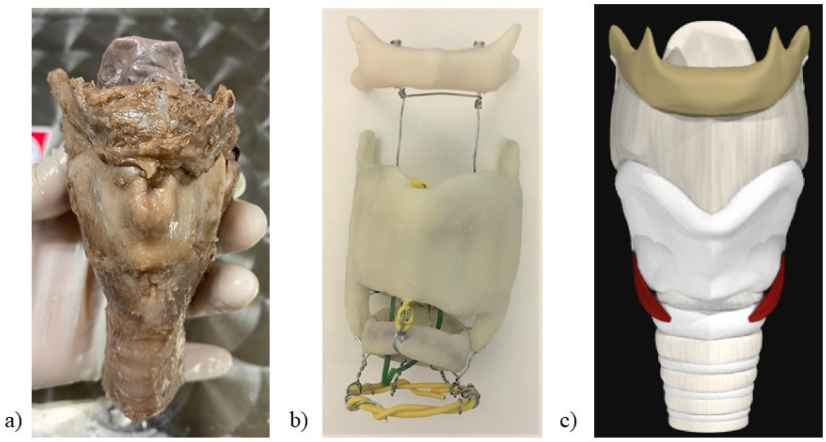

Figure 1. a) Cadaver specimen, b) physical model and c) 3D model.

2.1.2 3D Computer Graphics

3D computer graphics is widely used in many fields included in education because 3D graphics provide the students with visualization to understand the perceptions on the 3D objects such as different object size, space, range and relation to each other. Additionally, it helps the students with the simulated experiences to comprehend the objects movement, situation and visual reality such as 3D animation, and 3D simulation training (Tim & Daniel, 2002). The benefits of 3D visualization in teaching and learning can be simply observed and manipulated, animated, and scaled without damage to physical samples. Second, it gives the students infinite time with a study case. Third, it is easy to share due to digitalization (Dorothy Loftin, 2018). This advantage will help students to understand the knowledge with the help of 3D computer generated imagery.

2.1.3 Mobile Learning

Nowadays, mobile devices tend to be the most popular with users and their usage is growing. Due to the development of various applications to support humans to work successfully. Mobile learning is the application of mobile communication technologies in the field of education to deliver material and learning support via wireless communications devices. Additionally, the mobile learning emphasis on learning through movable contextual relevance, and other new features allows students to learn them interactively anytime and anywhere. There are numerous characteristic features of today's mobile learning. The following are some characteristics of mobile learning. First, the students can learn anywhere, which gives them flexibility. Second, it is timely because the students can learn rapidly, and the teachers can respond more timely to students' questions. Third, it provides interactive learning resources, such as chat rooms, Q&A areas, quizzes, and other interactive learning tools that can be used to encourage interaction between students and teachers. Lastly, it promotes collaboration, such as implementing collaborative learning activities in the classroom, which help improve communication between students and teachers (Ozdamli and Cavus, 2011; Yuan Jiugen and Xing Ruonan, 2016).

2.2 Mobile Application Design Process

The research went through the 3 steps of Laryngo-Application design processes as in figure 2.

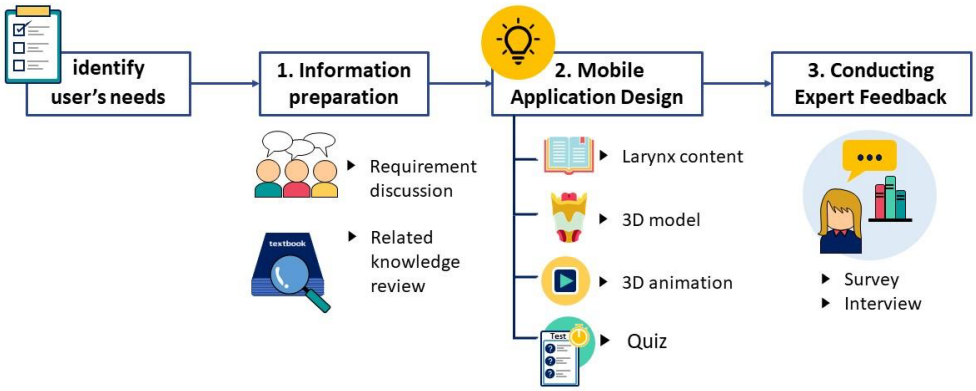

Figure 2. Process of Laryngo-Application.

2.2.1 Information Preparation

According to the application requirement, the prototype was designed to consist of four main parts, the larynx contents, larynx 3D model, 3D animation video, and quiz. The related anatomical contents and quiz questions are prepared by an anatomy lecturer, using six standard anatomy textbooks as references (Agur & F.Dalley, 2013; Marieb et al., 2017; Moore et al., 2014, 2015; Rohen et al., 2011; Tortora & Derickson, 2017). The 3D model of larynx, demonstrating its musculoskeletal structures, is manually created using the 2D figures in standard anatomy textbooks, cadaver specimens, and free-source 3D models as references. The prototype of the 3D animation video was created using the physical model. The aim of the 3D animation video was to demonstrate the functions of intrinsic laryngeal muscles and movements of the vocal cords. The quiz aimed to test the understanding about the knowledge provided in the mobile learning application and was organized into 2 types: identification of structure, and explanation of function and structural relation.

2.2.2 Mobile Application Design

This prototype consisted of four parts as in figure 3. First, larynx contents which contained the overall knowledge of the larynx were delivered to the students in two ways, via reading material and lecture video linked from an external source. Second, the larynx 3D model allowed the students to interact with it from 360-degree aspects. Third, 3D animation video which provided the students with the knowledge

of functions of intrinsic laryngeal muscles and vocal cord movements. Lastly, it was the quiz which briefly tested the knowledge of the students.

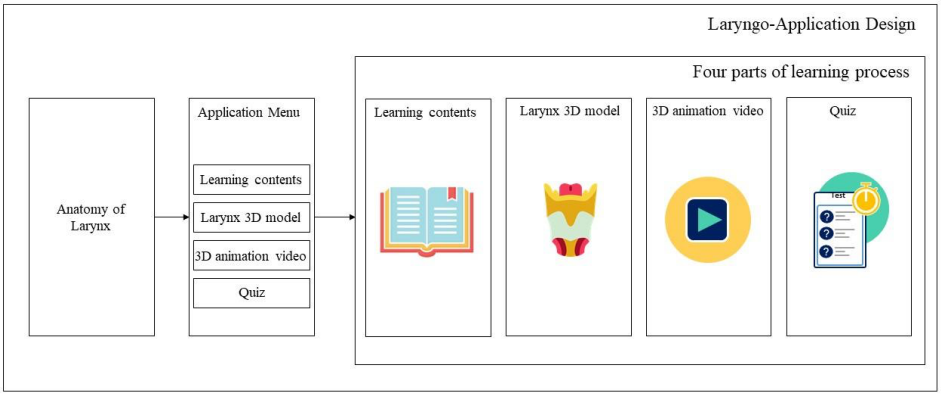

Figure 3. Four parts of learning process.

2.2.3 Conducting Expert Feedback

Five anatomy lecturers with at least three years of teaching experience participated in the survey and interview for providing feedback. The Laryngo-App prototype was tested by the anatomy lecturers. The survey questions regarding experts' satisfaction was conducted using a five-scale Likert scale provided via google form. There were ten questions, separated into four categories: user interface, design of 3D model, design of 3D animation, and appropriation for self-learning. In addition, the experts' suggestions were documented, then the data were analyzed for further development of the Laryngo-App.

3. Results and Discussion

3.1 Laryngo-Application Prototypes

The prototype of Laryngo-App was created as shown in figure 4. There are five categories: the larynx contents including reading material and linked video about overall structure of larynx, the larynx 3D models demonstrating its musculoskeletal structures, 3D animation video demonstrating the functions of intrinsic laryngeal muscles and movements of the vocal cords, and the quiz for self-evaluation of the students.

Figure 4. User Interface of Laryngo-Application prototypes.

3.2 Expert Feedback

This part presents the summaries from the expert's survey shown in table 1. In the user interface section, the result showed that 40% of the experts rated the design and button placement, appropriation of font

size and color, and ease of use as excellent, whereas 60% of them gave a good rating for appropriation and clear visibility of size and color of the buttons. For the 3D model of the larynx section, 80% of the experts rated the structure of the 3D larynx model as excellent. However, 20% of them rated as average. The experts rated the excellent for 60% on the display of the musculoskeletal structures correctly and another 40% for good. However, the experts rated good for 60% on the appearance of the 3D larynx model as close to the real structure, while rated excellent for 40%. For the 3D animation section, the experts' satisfaction strongly agreed that the animation demonstrated the laryngeal musculoskeletal structures and actions of the laryngeal muscles distinctly. The experts rated excellent for 60%, 20% rated for good, and gave 20% on average for animation and audio easy to understand. For the clear demonstration of structures and actions of the laryngeal muscles, experts rated excellent for 60% and 40% for good rating. For the Appropriate for self-learning lessons section, the question focuses on whether the application is suitable for self-learning. Experts were more satisfied, giving 20% of the ratings as average, giving 40% of the ratings as good, and 40% of the ratings as excellent.

Table 1. *The summary of responses to four sections from the experts*

S/N	Survey Questions	% Excellent	% Good	% Average	% Fair	% Poor
	User Interface					
1	Beautiful design, place the buttons appropriately	40.00	20.00	40.00	0	0
2	Size and color of the buttons are appropriate, clearly visible.	40.00	60.00	0	0	0
3	Font size and color are appropriately clearly visible.	40.00	20.00	40.00	0	0
4	Easy to access the information.	40.00	40.00	20.00	0	0
	3D model of the larynx					
5	The appearance of the 3D larynx model is close to the real structure.	40.00	60.00	0	0	0
6	Display the musculoskeletal structures correctly	60.00	40.00	0	0	0
7	The structure of the larynx is clearly visible.	80.00	0	20.00	0	0
	3D animation					
8	Animation and audio make it easy to understand muscle functions.	60.00	20.00	20.00	0	0
9	Animation clearly shows the structure and actions of the muscles.	60.00	40.00	0	0	0
	Appropriate for self-learning of lessons					
10	Application is suitable for self-learning.	40.00	40.00	20.00	0	0

The feedback from experts was valuable for application development as their suggestions aimed for the benefit of students. Based on the interview, they said that the application prototypes were interesting and could be further developed to be a useful learning tool for students. The details of experts' feedback and suggestions were shown in table 2. The experts gave positive feedback about the advantages of the 3D model as it enhanced 3D visualization and was easier to identify its structures, compared to cadaver specimens. They mentioned that the application was useful for online education,

especially during the current COVID-19 outbreak. For the content, they said that it was enough for students to read. For the quiz, the questions aimed for structure identification were appropriate. Whereas there was some negative feedback on the reading material, user interface, and quiz.

Table 2. *The summary of expert suggestions from the interview*

Component of the application	**Category of feedback**	**Feedback / Suggestions (number of experts)** (+ for positive feedback, - for negative feedback, and * for suggestion)
Larynx Contents	Content of the Reading Material	+ There was enough content for students to read. * The reading material should be made shorter and organized to be more easily read and understood. A brief review or a short note instead of a long text explanation. (2)
	Arrangement of the Reading Material	- Some pictures were too small and not significantly consistent with the text. - The text in explanation and label of the pictures were too blended. It should be more clearly separated.
3D Model	Feature	* Different kinds of structures should have different colors. (2)
	Presentation	* The sense of direction on the 3D larynx model must be added.
	Future Development	* The neurovascular structures should be added to the larynx model. * Additional organs could also be added.
3D Animation Video	Content	* The video explaining about movements of the vocal cord in general should be added for complete understanding.
	Presentation	* Beside sound and picture, some text should be added to the video to be suitable for students with various learning styles.
	Future Development	* There should be more videos in other topics, for example, cartilages of larynx, nerve supply of larynx, blood supply of larynx, the vocal cord movement of patient with recurrent laryngeal nerve injury, and the differences between vocal cord movement during high pitch and low pitch voice production.
Quiz	Objectives of the Question	+ The questions about structure identification were appropriate. (3) - The objectives of learning outcomes in the quiz were not clear. (2)
	Content	- Some questions about function and structural relation were too difficult. It might decrease the student's enjoyment in playing the application. - The reading material part is time-consuming to accomplish the quiz.
User Interface		* It would be convenient, if the students were able to go to specific topics by using keyword search. - The link between pages in the application was too complicated and took many steps. (Add main menu) * There should be a bottom to go back to the main menu in every page for convenience. (Add home button)
General Benefits		+ The application was very appropriate for online education, especially during the current COVID outbreak. + It had more advantage of 3D visualization and structure identification, compared to cadaver specimens.

An expert mentioned that the text in explanations and labels of the pictures in the reading material were too blended, suggesting that it should be more clearly separated. Some pictures were too small and not consistent with the text. For the user interface, it was mentioned that the link between pages in the application was too complicated and took many steps. The experts also suggested that there

should be a bottom to go back to the main menu in every page for convenience. For the quiz, they said that some of the questions were too difficult. The students might take a long time to read the material to complete the quiz. It might decrease the student's enjoyment in using the application. Two experts also added that the objectives of learning outcomes in the quiz were not clear. For the suggestions, two experts mentioned that the reading material should be made shorter and organized to be more easily read and understood. A brief review or a short note could be used instead of a long text explanation. It would be convenient if the students were able to go to specific topics by using keyword search. For 3D model, two experts said that the different kinds of structures should have different colors. One of them mentioned that the sense of direction on the 3D larynx model must be added. An expert suggested that the neurovascular structures should be added to the larynx model. For 3D animation video, they suggested adding some text to the video to be suitable for students with various learning styles. The video explaining about movements of the vocal cord in general should be added for complete understanding. There were some suggestions regarding future development. First, there should be more videos in other topics, for example, cartilages of larynx, nerve supply of larynx, blood supply of larynx, the vocal cord movement of patient with recurrent laryngeal nerve injury, and the differences between vocal cord movement during high pitch and low pitch voice production. Lastly, additional organs could also be added to the application.

In response to the expert feedback, the Laryngo-App will be developed before launching for the students. First, the contents of reading material will be reorganized. The summary of overall knowledge will be added. Second, the color of structures in the 3D model will be adjusted to make it clearer to differentiate. Third, the 3D animation will be presented with both audiovisual and text media. Lastly, the quiz questions will be separated into two levels: basic and advanced. The difficult questions will be asked in the advanced level.

4. Conclusion

In this research, we proposed a prototype of Laryngo-App with 3D visualization in anatomy of the larynx. The results from experts' satisfaction and suggestions were very useful for further application development. Based on the survey results, it may be concluded that for the user interface sections, the expert tended to agree that it was easy to access the information and had a friendly user interface. For the 3D model of the larynx section, the experts mostly strongly agreed that the structure of the larynx was clearly visible while the musculoskeletal structures appear accurate. For the 3D animation section, the experts strongly agreed that the animation distinctly demonstrated the laryngeal musculoskeletal structures and actions of the laryngeal muscles. Nonetheless, the experts agree that the Laryngo-App could promote self-learning among the students. The expert suggestions regarding its application could be summarized as follows. First, for the larynx contents, the experts suggested that the reading material could be shorter and well organized. For the larynx 3D model, experts strongly suggested using different colors on the different structures to make each component of the larynx more clearly differentiated. On the 3D animation video, the experts recommended adding text such as keywords for a good understanding on the video presentation. For the quiz, the experts suggested that objectives of learning outcomes must be clear. However, the expert mentioned that the Laryngo-App was very helpful for online education, especially during the current situation of COVID-19 outbreak, because the students could learn anytime and anywhere. Besides, 3D visualization has given the benefit of structure identification, compared to cadaver specimens.

Future works, the first version of Laryngo-App will be implemented in Anatomy courses for the second-year medical students and dental students at Mae Fah Luang University, Thailand. Satisfaction and learning outcome of the student will be studied for the future experiment.

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