Development of AR Learning Assistance Tool for Clay-Sculpting 3D Model

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***Abstract*— Clay sculpting is one of the skills that can be acquired through learning and training. In a traditional method for learning to sculpt a clay model, learners tend to use 2D images as references for sculpting their works. In this paper, we propose an alternative method for learning to sculpt a clay model using the AR technology to provide different views of a clay-sculpting 3D model. It can increase learners' perception, attention, and understanding of proportional details of reference models since they could interactively view a reference model in 3D. There are 2 modes for viewing a 3D model which are a normal 3D and AR mode. The proposed tool is mainly developed with Unity, Autodesk Maya, and Clip Studio Paint. The evaluation of this tool is done on 30 university students who are currently studying in the multimedia and animation field. Participants are divided into 2 groups. Each group is further split into small teams of 3 persons. In each round during an experiment, we swap a turn of using the application in each group. A questionnaire is used to obtain feedback on our tool after experiments are finished. The result shows that participants have positive opinions about our tool. They tend to prefer viewing a 3D model in a normal 3D mode than an AR mode. In conclusion, our proposed application is a great learning assistance tool for clay sculpting.**

Keywords—AR, 3D Sculpting application, 3D Sculpting learning tool

I. INTRODUCTION

Learning is a method of translating and transferring knowledge and skills [5]. Learning methods and materials are important to facilitate a learning process. There are many techniques that could be used, including documents, slides, videos, music and games. Each technique has its own characteristic and strength [2][3][6][9][12].

In this early year, technology has become a part of human life. The mobile device is a technology that is easy to access. Thus, the rationale behind this research is to address a difficulty to learn sculpting 3D model, using Augmented Reality (AR). AR is widely known and has been used in many fields [1][9]. By this method, the learner will only require a smartphone or a device that has a camera, so that the full render 3D model can appear on the screen. AR can also provide the dimensional model [3], in which users can see the model in every direction. The users can easily learn and understand the shape of a 3D model.

In contrast, a traditional way of using a 2D image as a reference could cause a difficulty in comprehending the model. This leads to a time consuming on sculpting a clay model. We also found that some users are unable to detect accurate measurements of a 2D image because it does not provide any depth information. This research will improve the visualization and reduce blind spots of using a 2D image as a reference [3][6][8], based on a 3D model visualization and an AR interaction approach.

There are many researchers found that AR was used in many subjects [1]. Some of them use it to increase a utility of a university-level teaching, a quality of learning, and a student engagement [2][3][4][6][8]. They focused on fix preview problems and increase engagements. The existing AR based systems were evaluated on participants ranged from pre-school students to university students. Several methods for measurements were used in the evaluations, including A/B testing and pre-test/post-test. The evaluation results showed that the participants have positive opinions in variety points after using an AR as a learning tool. There exists research that used the AR technology for educational purposes [13].

Thus, the objective of this research is to create an AR application that render a computer graphic 3D model to be used as a reference to learn a clay sculpting. By this method, an AR application will support the user by generating a 3D model on a user's device. A user can interact with the 3D model by rotating and visualizing the model in any perspectives. We evaluate our proposed learning tool with 30 university-level students who study in a multimedia and amination area. Each student will be asked to sculpt a clay by using a 2D image and our AR based 3D model as a reference in each turn. Finally, they will be asked to evaluate the tool by answering a questionnaire.

The rest of this paper is organized as follows. Section II explains techniques to develop an AR learning assistance tool for clay-sculpting 3D model. Experimental results are shown in Section III, and conclusions are drawn in Section IV.

II. METHOD

In this research, we focus on creating a learning tool for multimedia students. The tool uses AR technology to visualize a 3D model. It will be compared against a traditional technique which uses a 2D image. A content of human anatomy is used for clay sculpting art, as a case study in this paper. The software that we use to develop this application are the Unity 3D Engine, Autodesk Maya 2018, and Clip Studio Paint. Unity is used for coding with C# scripts while Maya and Clip studio are used for creating graphics. Vuforia Engine for Unity is used in an implementation of the AR technology. First of all, the system design will be explained, followed by graphic and material design. The last subsection is an experimental design.

A. System design

This application is developed for students that study in the field of the art and digital media. It mainly relies on an AR technology. It also has a function for previewing a 3D model.

This subsection explains about designing the structure of an application in the programming section. First, we develop a conceptual design of an application, then the system architecture is designed with respect to a conceptual one.

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Since we develop an application in an object-oriented manner, a class diagram is used to describe the system's classes and their relationship. Finally, a flowchart is used to explain the workflow and procedures of each function in our application.

1) Conceptual design: The conceptual design describes the idea of the application as shown in Fig 1. Since this application will be used as a learning tool for model sculpting, it displays a 3D model to a user as a reference for them to sculpt a clay model. The step of using this application started with opening a device for viewing content. Then, a user can view a 3D model in an AR view. A user can switch a mode into a 3D mode which is a mode that just simulates a 3D model into a mobile screen. In other words, it is for a user to view a 3D model like a normal regular 3D viewer program. For the AR mode, the model will be set on a marker position in the real world. A user can view it in 360 degrees or any directions. This application is designed for using offline, so it can be used without the internet connection after the installation is done. Our desired user persona is a student are 15 – 24 years olds who studies in the field of fine art or computer graphic. The objective of this application is to help users efficiently learn clay sculpting. A user can be either a male or a female. The application itself is free to use but it has to be installed on a smartphone. So, this application requires users to have a smartphone.

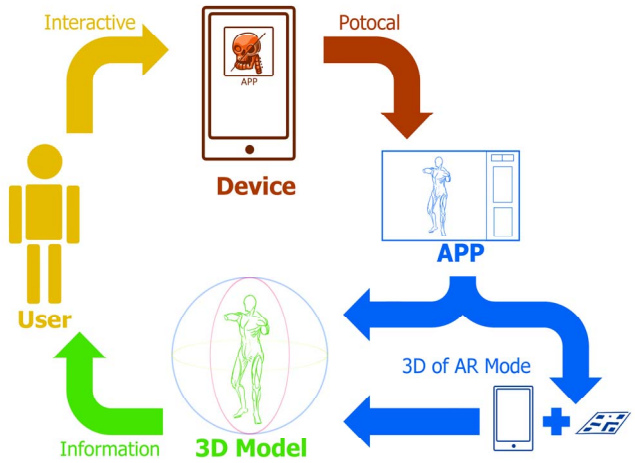

Fig. 1. The conceptual design of this application.

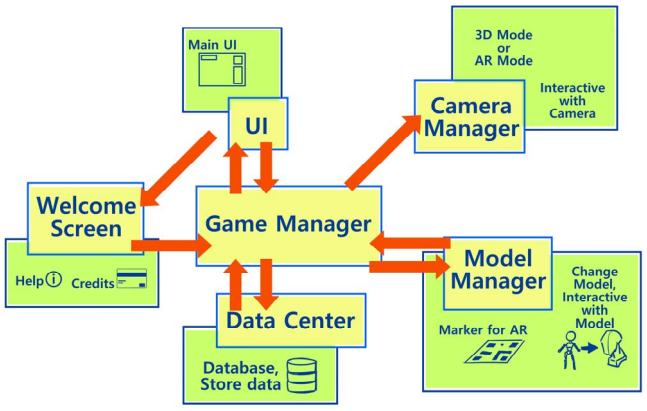

Fig. 2. The design of the system architecture in this application.

2) System Architecture: This diagram explains classes in this application as shown in Fig 2. There are 5 main classes which are UI, Game Manager, Camera Manager, Model Manager, and Data Center. Firstly, the UI class will focus on creating a User Interface consists of buttons, images, and checkboxes. It is also responsible for maintaining a function in each UI component in an application. Moreover, the UI component has a helpful tool to show a useful tutorial to a user. Secondly, the Game Manager will focus on managing everything in a system. So, it associates with every component and transforms a value or function between each component. The system will contain values and parameters that are frequently used by many classes.

Next, the Camera Manager class will focus on manage how an application is displayed. This application can display a 3D model in two modes which are normal and augmented reality (AR) view. Another component is the Model Manager class. It will focus on managing the main model in this system. A user can change or load a model that has been saved in the system. A user can also interact with a model by changing its pose. The model can be viewed in either normal 3D or AR mode. The next component is the Game Manager. It will maintain the model that has been selected. Next, the Data Center component will be a section for storing data into a database. This component just only transforms values and parameters into a database type. Another component is the Welcome Screen. This component will be shown at the beginning of an application to display a description of this application.

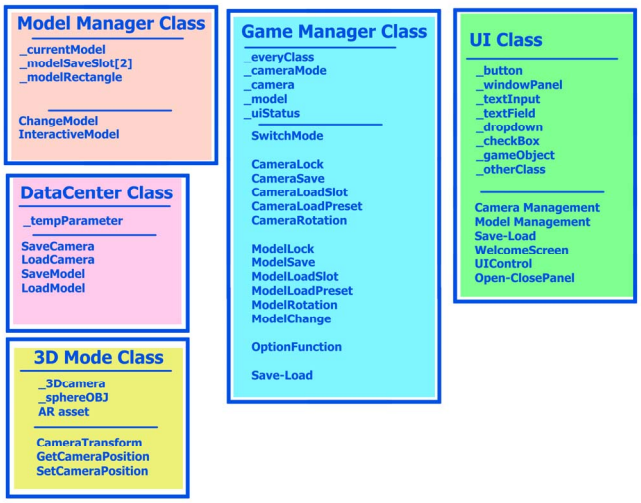

Fig. 3. Class Diagram design: explanation of application's classes and their functions and parameters.

Class Diagram: It is a diagram that explains classes and relationship among them in this application. The application step will start running from the Game Manager class as shown in Fig 3. When a user takes an action, the Game Manager will select and run a corresponding function to an user's action. For example, when a user presses on a switch mode button, the UI class that manages a switch mode button will send a signal to a Game Manager class to run a switch mode function. Then, it will tell a Camera Manager to switch and change a camera status. The parameter will not be messy if programming is done in this manner. Camera Model is a class created for controlling a camera, view type, and set a position

of a camera from the saved position. We call the switch camera view in this application as a switch mode. There are two modes in this system which are the 3D and AR mode. The mode is switched when a user pressed on a switch mode button. The parameter in this class will consist of camera objects, 3D spheres, and AR assets. A camera object is for rendering an image. The angle of an image depends on the position of a camera. So, the system needs to have a camera object to control it. Next, a 3D sphere is an object that is used for controlling a camera. ARCamera from Vuforia is used for changing a regular display into an AR display. It is an object that can automatically display an image to a device's camera. Vuforia also has a library named "ImageTarget" that can instantiate an AR marker. There are 3 main functions in this class which are CameraTransform, GetCameraPosition, and SetCameraPosition.

Game Manager is a class for managing entire system. This class contains a main parameter that is used in other classes such as Camera Manager and UI class. A camera is used on UI class and camera mode. Functions in this class control other classes. They also help in passing a value from one class to other classes. Moreover, they also send a command to other classes. For example, UI class is a class for creating a user interface that may consist of a button. However, a button is used in a function in the Game Manager. The functions in this class are SwitchMode, ChangeModel, UI, LockObject, and Save-Load function.

Model Manager is a class that manages 3D models in this application. This class will do things like choosing, posing, saving, loading, and sending the name of the model. Parameters in this class are model that are currently in use. It also contains slots for storing models when a user saved them. A parameter for storing state and position of a model are also in this class. The function in this class are getters, setters, and ChangeModel function, which is a function to transform or change posture of a model. User Interface is a class for creating a user interface for this application which include buttons, images, and sprites. Parameters in this class are buttons, images, checkboxes, toggles, drop-down lists, and panels. The function in this class is more focusing on the creation of an overlay of this application. It also focuses on sending a signal or a user's command to another class. Data Center is a class for handling data operations between an application and a database. This class has parameters for storing values in numbers and characters. It has functions for saving, loading, encoding, and decoding data. It is only accessible from the Game Manager class.

B. Graphic design and Material

This tool is implemented using Clip Studio Paint and Autodesk Maya. Clip Studio Paint is a digital drawing software that is used to create 2D images while Autodesk Maya will be used for sculpting a 3D model.

1) Idea and Research: Graphics and materials in this application are designed for assisting users in learning human anatomy. The user interface in this tool is inspired by the general 3D modeling software. Most 3D modeling software has a function to control a camera and sculpt a model. For instance, users can manually control a camera by pressing on the controller buttons. At present, an art student tends to learn to sculpt a clay model using a model statue [8] as a reference. This application aims to help users to learn the human anatomy such as the head, figure statue, female body and wooden drawing manikin using a digital 3D modeling tool.

2) Sketch design: User Interface (UI) are designed to have 4 input components which are buttons, dropdown lists, text input fields, and checkboxes as shown in Fig.4 . Each component will call its corresponding function in a unity script to perform some particular function. The first component is a button that is used for triggering a function for a single time. For instance, saving a model or toggling some booleans variable. There are several buttons in this application since they are basic input components. Next, a dropdown list is used to allow users to make a selection which is the selection of a model. Another component is a text input field which allows users to rotate a camera and model by entering the rotation angle.

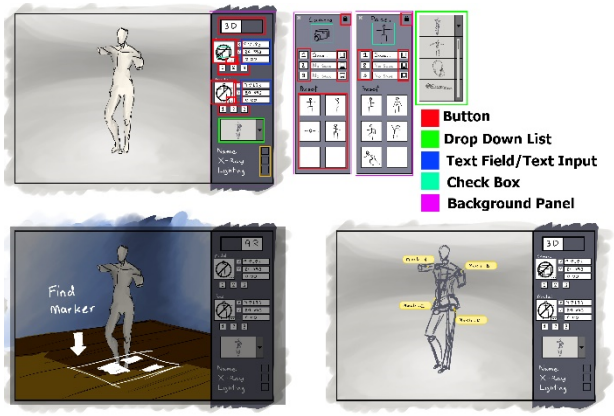

Fig. 4. User Interface design: the design of user interfaces in this application.

Apart from the user interface, four different versions of models are sketched. The first one is the human body showing a muscle system. This model is designed for learning the position and shape of the human muscle. The second one is a full female body with the skin. This model will show a proportion of female shape. The next one is the human head with a basic geometry shape. This model will be used for studying the structure of a human head. The last one is a wooden manikin for drawing. This model will be a tool for learning the structure and proportion of a human body.

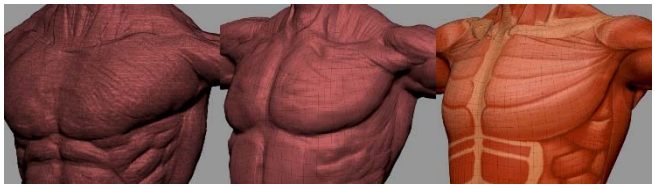

Fig. 5. The density of polygon on the model before and after applying retopology combined with texture.

3) Implementation: Clip Studio Paint software is used for a sketching process. It is also used to create user interface components, textures of a model, and references for 3D modeling. Autodesk Maya 2018 has been used to create a 3D model because this application is focusing on the mobile platform. Hence, it should be light-weighted while still preserved its good rendering quality. The low polygon model is created and Autodesk Maya is used for creating a basic

form for a model as shown in Fig. 5. Then, the sculpting software is used to create the shape of the model and sculpt its detail. It can increase polygons and allow the addition of details to a model become easier. After finish adding details, a retopology method is applied to a model. Then, the last process is to develop the user interface, textures, and riggings.

C. Experimental design

1) Method: In the experiment, the learning simulation is conducted. There are 30 subjects (21 males; age 18-26 years old, mean±SD = 22.56±1.56) that participated in this experiment. Every subject is the 2^{nd} – 6^{th} years students in Faculty of Information Science and Technology, Mahanakorn University of Technology. We gave a task to students to model a clay for 2 hours for two times. The method for testing is splitting students into two groups which are A and B. We will let students in each group use our application in the first time or the second time with respect to their on each group.

In group A, we will let participants use an application while doing a test in the first round. Then, we let them do a test without application in the second round. In the group B, we will do the same thing but switch the task in each round with the group A. Hence, students that belong to the B group will use the application on the second round. So, we can evaluate our application with A/B testing and Pre/Post-test method. The student will be taught to use an application in the first 15 minutes before the test is started. Then, after finish two rounds of testing. The student will be asked to do a questionnaire on how effective of an application and asked to provide comments.

2) Evaluation: In order to evaluate our application, the A/B testing method is used for estimating the impact of an application between two groups. The Pre/Post-test method is also used to find the improvement of learning of the student.

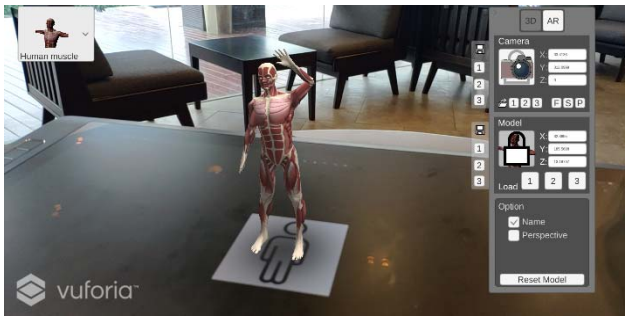

Fig. 6. The final image of the application.

III. RESULT

The application was experimented on students from Faculty of Information Science and Technology, Mahanakorn University of Technology. The class of 30 students who are 18 to 26 years old.

A. Application product results

The final product can meet the expectation of the concept design. The Unity engine has tools that can create its content and can publish an application for Android devices. However, there are some modifications from the first draft. There is some redesign of the user interface to improve user experience on an application. There are some minor changes to make it more comfortable and practical. An application still has main features. A user can view and interact with a 3D model. A camera is also interactive and can switch between 3D and AR mode interactively. A user can save or load a camera and model. There are few optional functions like light controlling, model name displaying, camera POV changing. The final user interface of this application is shown in Fig. 6.

Fig. 7. Students testing: Student sculpting a clay model during testing.

B. Learn to model human clay using AR.

The testing is set up to let students sculpt a clay like in a regular classroom. Students had sculpted a clay 3D model with clay materials for 2 hours and they did it twice. Students are divided into two groups which are group A and B. For group A, students were allowed to use an application on the test in the first round while students in group B Group were allowed in the second round. When a student wasn't allowed to use an application in each round, students were allowed to use the 2D image in the testing instead. The assignment that we gave to a student is to sculpt a human head. They have to model a basic shape of the human head in the isometric angle view as shown in Fig. 7. The model can be sculpted in either height or round relief but students have to do it twice so that they can compare the difference of learning between the first and second round.

C. Questionnaire

The questionnaire has two sections which are score ranging and comment section. Both sections use the same groups that represent each aspect of an application. The aspect that we interested in are Leaching Material, User Interface, Multimedia Feature, Interactive Function, and Practicability.

1) Score ranging section: In this section, we have five topics of questions. Each topic has 3 questions. Therefore, there are 15 questions in total. The question will ask a student in detail depends on each topic. The question focused on performance, usability, how the effectiveness of application, and the comparison between the application against the traditional method, the application performance, and usability. Students have to answer every question on this section.

TABLE I. QUESTIONNAIRE TOPICS FOR SCORE RANGING SECTION

Question	Topic of question
Teaching material	
Q1	Is using an AR for a learning technic useful than 2D image?
Q2	Is using an AR for a learning technic improve your leaning?
Q3	Is using an AR for a learning technic present a content clearly?
User Interface(UI)	
Q4	Is the UI in this application appropriate to the 3D model learning clearly?
Q5	Is the UI present a function clearly?
Q6	Is the UI design pattern international?
Multimedia Feature	
Q7	Is the image quality in this application better than 2D image?
Q8	Is the image that get form application is useful than 2D image?
Q9	Is media in this application suitable for learning 3D model sculpting?
Interactive Function	
Q10	Is the interactive of an application useful than using 2D image?
Q11	Is the interactive of an application suitable to be use for teaching 3D model sculpting?
Q12	Is the interactive of an application useful for 3D model sculpting?
Practicability	
Q13	Using AR application for learning 3D model sculpting is useful.
Q14	Using AR application for learning 3D model sculpting is comfortable
Q15	Using AR application for learning 3D model sculpting is reach the goal and want to use more.

The questionnaire used a point-scale range from 1 to 5 for scoring, where 1 is the lowest point and 5 is the highest point. Table II shows the number of scores that students gave to each question. In each row, the upper integer represents the number of students who gave a score in each column. The lower one is the percentage of students who gave a score in each column to that question. An average score for each question is shown in a spider chart in Fig. 8.

2) Comment section: In this section, students were asked to provide their suggestions for this application with the same aspect as in the scoring section. Comments are classified into topics of comment as shown in Table III instead of positive and negative comments. In other words, we ended up with their comments on the learning with our application, practicability, understanding, suggestion, problem, and general comments. We founded that most of the comments tend to be positive and students said that our tool is better than the traditional one.

TABLE II. RESULT OF QUESTIONNAIRE ON SCORE RANGING SECTION

Question	Score 1	2	3	4	5	Avg.
Q1			3 10%	11 36.67%	16 53.33%	4.43
Q2			6 20%	13 43.33%	11 36.67	4.17
Q3			1 3.33%	14 46.67%	15 50.00%	4.47
Q4			4 13.33%	17 56.67%	9 30.00%	4.17
Q5		1 3.33%	7 23.33%	17 56.67%	5 16.67%	3.87
Q6			7 23.33%	20 66.67%	3 10.00%	3.87
Q7			2 6.67%	13 43.33%	15 50.00%	4.43
Q8			4 13.33%	11 36.67%	15 50.00%	4.37
Q9			5 16.67%	12 40.00%	13 43.33%	4.27
Q10			6 20.00%	16 53.33%	8 26.67%	4.07
Q11		1 3.33%	3 10.00%	12 40.00%	14 46.67%	4.30
Q12	1 3.33%	1 3.33%	4 13.33%	11 36.67%	13 43.33%	4.13
Q13			5 16.67%	14 46.67%	11 36.67%	4.20
Q14		1 3.33%	4 13.33%	14 46.67%	11 36.67%	4.17
Q15			6 20.00%	11 36.67%	13 43.37%	4.23

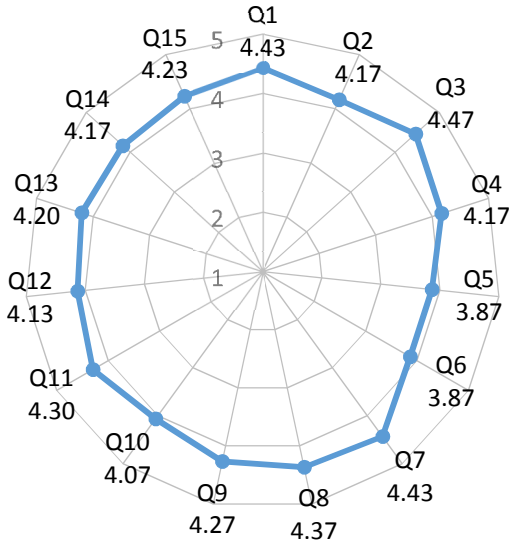

Fig. 8. Results of players' satisfactions with the developed application.

a) Teaching Material: Most of the comments in this aspect are positive. There are many students said that our tool is better than a traditional method. It is more suitable to use as a learning tool and can visualize the model in various directions. There is only one student said that she could not see the 3D image as a 2D image and application is hard to control and should support all mobile devices.

TABLE III. TABLE OF QUESTIONNAIRE TOPIC: COMMENT SECTION

Order	Topics of comment
1	The usage of AR as the teaching material.
2	The UI of an application.
3	The multimedia features of an application.
4	The interactive of an application.
5	The practicability of the learning with AR

b) User Interface: An opinion on this part is a little diverged. Students said the user interface is easy to use and they loved a feature to save and load. However, some students said that some user interface is too small and difficult to understand. The controller of the model is hard to spot and should be more user-friendly. They suggested increasing the size of the user interface for the ease of use.

c) Multimedia Feature: All comments in this topic are positive. Many students said multimedia features in this application are easy to understand, various, and modern technology is used. It a helpful and useful tool for learning. There are suggestions that this application should provide more 3D models.

d) Interactive Function: Most comments in this topic are negative. Many students complained about the camera control that it is hard to use since the mechanic behind it made a user hard to use. However, some students said that the transformation of the camera was smooth and the camera rotation was useful. Students said that it would be better if the application has a screenshot capturing feature and tutorial video on sculpting a model. There are students who want to use this application in a real classroom so they can improve their clay sculpting skills.

e) Practicability: Most comments on practicability are positive. 7 of the students said that it was convenience to carry since the application is running on the mobile phone. Some of them said that it was better than learning from a 2D image. However, there is a little problem with camera control and students said that they could not get used to it.

IV. CONCLUSION

To summarize, the tool for learning modeling clay is successfully developed. In the implementation, Unity can manipulate its design and an application can run on most of the students' devices. There are some compatibility issues during the experiment since many students used iOS devices which is not currently supported by our tool. There is also some problem of compatibility on some Android devices with the AR function from Unity. From the experimental and questionnaire part, it is better to have more reference for students to learn. Some student said that they would like to use an application again. The 3D model was helpful since it gave more information better than a 2D image. However, students feel hard to animate a 3D model in an AR part and it should be optional. An application should have an option to capture a screen when using AR mode (figure 6) so students can use them as references. The function in this application is useable but there are interesting suggestions such as screen capturing feature and tutorial videos. We might include them in the future work. The application already has usability and functional. However, some user interface components and controllers have to be modified for improving user experience. There are several metrics that we can use to improve the current design [13].

In conclusion, the application can help the student learn to sculpt a clay model. There are many interest things and something that is unexpected. Clay model sculpting is a practical skill that can be learned by training and practicing. However, students need to understand the shape of things that they wanted to sculpt. Using this application can be an optional and alternative tool for students to use for their learning.

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