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Math teaching aids in shape topics for PT3 students

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Abstract. Mathematics is a significant pillar in science as mathematics has built technology, machines and digital as progress in this century. Therefore, mathematics is essential to practice since childhood. Although various efforts have been made in updating the teaching methods to students by teachers, students still have difficulty in understanding mathematical concepts, especially in the topic of form. Most students memorize more than they know logic and discoveries in mathematics. Teaching aids are interactive software that can be used simulated. Therefore, the goal of this project is to develop mathematics teaching aids for shape topics for Form Three Assessment (*Pentaksiran Tingkatan Tiga* - PT3) students. The study involves three main phases which are initial research and data collection, design and implementation and assessment.

1. Introduction

Computer technology is developing as development in the field of computers is emphasized because computers are now widely used by people around the world as a routine and daily life. Along with that, software technology is also being renewed and developed especially for the young.

In learning, teachers face challenges in teaching where each individual has a different intellectual understanding from each other [1]. This challenge should be addressed by using technology, such as the use of teaching aids for subjects that teachers handle. According to Tolbert [2], the use of teaching aids shows a positive effect on student achievement, where students can easily understand the concept of learning.

Furthermore, instructors also use teaching aids along with computers in helping weak students for certain subjects, especially mathematics. This is because there are students who have problems in understanding the basics of mathematics from the beginning despite knowing the calculation for the question. [3] has investigated the metacognitive behaviour of students in solving mathematical problems of Form Three Assessment (*Pentaksiran Tingkatan Tiga* - PT3). In Malaysia, the students in the age range of thirteen to fifteen years will sit the PT3 examination. A recent study in [4] claimed that the Higher-order thinking skills (HOTS) mathematical problem-solving was first introduced in the PT3 in 2014. However, so far, there have been no studies of students' ability to solve the mathematical problems in PT3 assessment. Therefore, this paper aims to describe the development of teaching aids in three-dimensional (3D) for shape topics in mathematics, and a case study is the PT3 students.

2. Problem Background

Nowadays, technology, machines and digital have introduced new knowledge and discoveries. All of this starts from mathematics since it was first discovered and studied by some of the earlier figures for so long. To date, mathematics has changed our environment directly or indirectly in our daily lives. Therefore, mathematics is very important to be taught since kindergarten.



Teachers today strive to improve their teaching methods so that the learning objectives for students are more successful. The main goal of teachers in teaching mathematics lessons is to help students' proficiency in mathematics, that is, the ability to understand, evaluate, and apply mathematical knowledge regardless of any situation related to mathematics. Based on PT3, the constructs that need to be given to students are such as skills to remember, understand, apply, solve problems and evaluate through written tests and types of items such as Multiple-Choice, *Objektif Aneka Pilihan* (OAP), *Objektif Pelbagai Bentuk* (OPB) and *Subjetif Respons Terhadap* [5]. Mathematical topics such as shapes are very relevant and require those skills.

However, students are more likely to memorize formulas to perform calculations in answering mathematical questions than to understand the intent or concept of the question. Although students are proficient in making calculations, students will have difficulty in choosing the formula that needs to be used to solve mathematical problems. This is because students memorize the facts or how to use the formula alone without feeling the mathematics as a process of discovery and exploration in depth. For students, mathematics is known as a call-and-response game [6]. Furthermore, for students, it is difficult to imagine the proper view of the shape by looking at static image in text book.

Therefore, there are several other methods used to teach students in the field of mathematics in line with the era of technology. Among them is interactive software where mathematics is taught in a simulated calculation controlled by the player. The simulation software provides space for students to explore more deeply about mathematics while stimulating interest. Examples of such software can be found on the Math is Fun website, where the site provides several types of mathematical software from various subjects, such as Broken Calculator, where players have to answer number operations based on the function of the calculator button provided only [7]. This software provides challenges and space in exploring each solution that can unravel the given questions.

In conclusion, the problem of the frequency of memorizing the use of formulas without the internal exploration of the subject will make it difficult for students in understanding the subject of mathematics such as shape. Among other teaching methods to curb this problem is to use interactive software taught in numerical simulation to increase students' interest in exploring solutions to each mathematical problem. Thus, teaching aids can be used to assist students in mathematics subjects for shape topics.

3. Background Study

Studies on existing software are conducted to compare the characteristics of teaching aids and the concept of teaching aids that has been used in this study. The pattern of teaching aids software is important to identify the concept of teaching aids that are appropriate to the target user, which are PT3 students in Table 1.

Table 1. Mathematic teaching aids software comparison for shape topic.

Software	Features		
	Operation	Software Patterns	Special Features
Open Source Physics	The volume formula for a rectangular pyramid	Change the shape of the pyramid based on the value of area and height	Allows the user to observe the shape of the pyramid as a whole
Geogebra	The volume formula for cylinders	Change the shape of the cylinder based on radius and height	Has a detailed operating indication of the volume
Math Interactives	No Operations	Quiz or simulation to show shape by surface area	Produced in 3D and this type of software is in the form of simulations and quizzes.

4. Project Methodology

In order to build mathematics teaching aids for PT3 students, this project use computer-based, and involves several phases methodology, as shown in Figure 1.

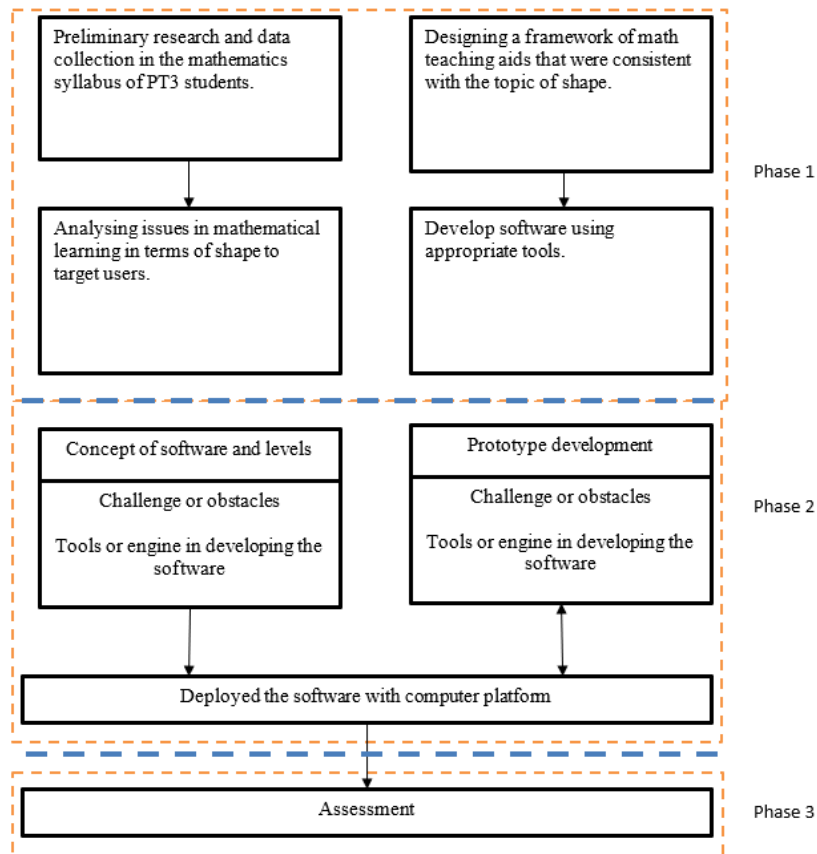


Figure 1. Project Methodology.

Phase 1 is focused on exploring past approaches to develop teaching aids for mathematic in the topic of shape, including how their software achieve interactive learning for PT3 students in determining basic formulas and operations. PT3 syllabus in mathematics has been collected, data were collected by referring to books to find out how to learn secondary school and basic arithmetic operations.

Based on the information found in the previous phase, phase 2 is the invention phase for mathematic teaching aids software in terms of shapes is needed to assist in the learning of shape topics interactively. The main challenge in this project is to illustrate the syllabus available from books to 3D software.

Phase 3 discusses the evaluation of mathematic teaching aids in terms of shape, Shape Lab for computer platforms. This includes comparisons between existing teaching aids software and showing improvements if needed. The evaluation process is carried out for the usability and functionality of the software developed.

4.1. Description of Technology Used

The technologies used to build this software are Unity and Blender. Unity is a real-time engine developed by Unity Technologies in June 2005. The Unity engine is capable of producing applications, systems or software either 2D or 3D. This technology is used to produce 3D computer software using C++ or C# programs to produce the required functions according to the scope of this project.

Blender is a free and open-source 3D computer graphics software. The use of Blender is to create animations, visual effects, they create models and so on. Blender software can be used to facilitate the

software development process of math-specific teaching aids in Unity engines. Most of the forms used for this project are produced by the Blender program. Table 2 list the hardware requirements for this project and Table 3 list the software requirements for this project in general.

Table 2. Hardware Requirements.

Hardware	Model
Computer/Laptop	ASUS TUF GAMING FX505
Central Processing Unit(CPU)	Intel Core i5 8th Generation
Graphic Processing Unit (GPU)	Nvidia GeForce GTX 1050
Random Access Memory (RAM)	12 GB
Hard Drive Storage	1 TB

Table 3. Software Requirements.

Software	Model/Version
Operating Systems	Windows 10
Application Development	Unity 2019.1, Visual Studio 2017
3D Modelling Engine	Blender

5. Design

The concept used for this project is to learn the concept where the user puts the answer key in the keyboard and sees a simulation of how the shape is designed, involving multiplication for volume calculation.

In the early stages, users need to press the play button on the page to use Shape Lab software. Users will see tutorials on how to use the software such as how to run, and answer questions. After that, they will start playing on the first level which is the square level. The main instructions for this software are about movement and how to answer the design for squares, triangles and circles.

There are six shapes for each type of shape displayed in a wireframe line, to indicate the shape is a question that needs to be filled. Each shape has variations in terms of scale on each part of the formula such as length, height and width. Therefore, each shape does not have the same length, height and width values. The framework of teaching aids software, Shape Lab is shown in Figure 2.

5.1. Home Page Interface

The interface design, or referred to as the interface design, refers to the information displayed to the player as a guide on how to play Shape Lab. When the user opens this software, the interface provides two menus, namely Play and Quit. Users need to press the Play button to start using this software in Figure 3.

5.2. Shape Question Interface

The user needs to enter all the answer values, i.e. length, height and width of the rectangle, as shown in Figure 4 (a). When the answer value is given, the shape will be designed in the preview provided in the middle of the question page. Each value of the answer will affect the appearance of the answer to that shape. When the user fills in all the answer values, the player has to press the Apply button to check the answer. If all the answers are correct, the question is closed, and the shape for the question is displayed in blue, as shown in Figure 4 (b).

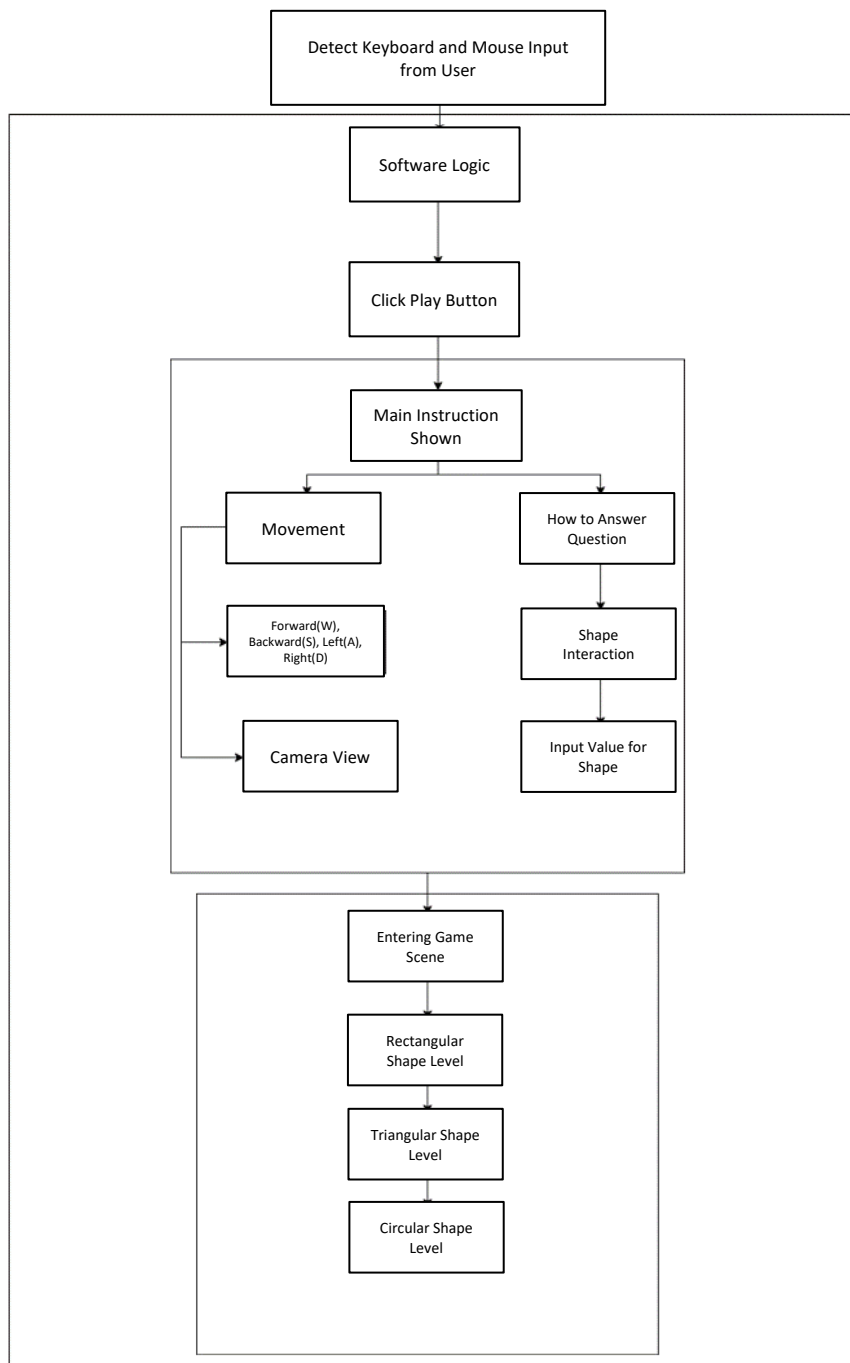


Figure 2. Shape Lab framework.

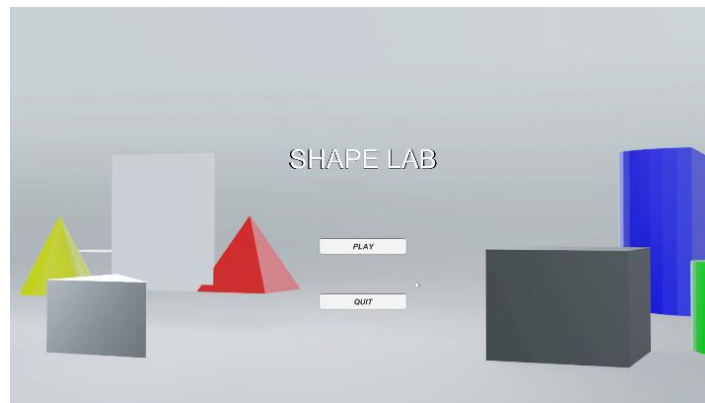
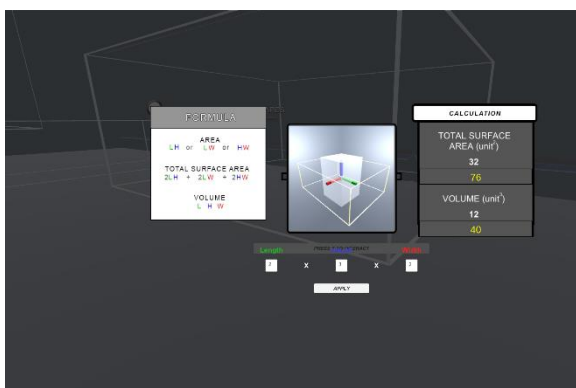
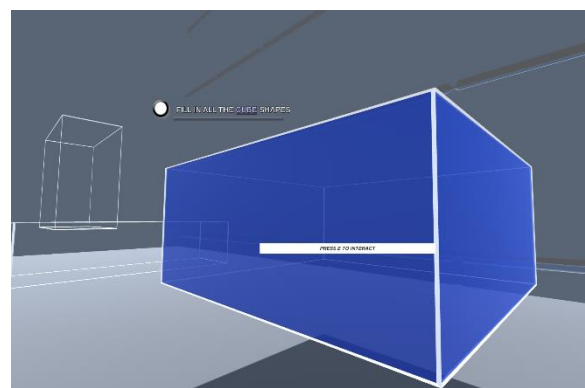


Figure 3. Shape Lab software homepage.



(a) Question interface



(b) Successfully answered questions

Figure 4. The Application.

6. Implementation

There are three main implementations in developing this software, namely character movement and camera view, and arithmetic shape calculation interactions along with simulations and calculations for calculated displays for area and volume.

6.1. Implementation of Character Movement and Camera View

Basically, in teaching aids software should involve character movement and camera views to provide a 3D space experience to the user. In addition, character movement can be controlled using the keyboard provided by Unity Engine [15]. Generally, to move an object, we need to change the transformation value in terms of translation such as X and Z. To change the translation value of X from the user character, the float variable x is used and takes the input of the Horizontal keyboard, namely W and S. To change the value translation Z, float z variables are used and take the input of Vertical type keyboards, namely A and D. All of these coding implementation is shown in Figure 5.

```

//Gravity Ground Check
isGrounded = Physics.CheckSphere(groundCheck.position, groundDistance, groundMask);

if(isGrounded && velocity.y < 0)
{
    velocity.y = -2f;
}

float x = Input.GetAxis("Horizontal");
float z = Input.GetAxis("Vertical");

Vector3 move = transform.right * x + transform.forward * z;

controller.Move(move * speed * Time.deltaTime);

velocity.y += gravity * Time.deltaTime;

controller.Move(velocity*Time.deltaTime);

float mouseX = Input.GetAxis("Mouse X")*mouseSensitivity*Time.deltaTime;
float mouseY = Input.GetAxis("Mouse Y")*mouseSensitivity*Time.deltaTime;

xRotation -= mouseY;
xRotation = Mathf.Clamp(xRotation, -90f, 90f);

transform.localRotation = Quaternion.Euler(xRotation, 0f, 0f);
playerBody.Rotate(Vector3.up * mouseX);

```

Figure 5. Coding for movement and camera rotation.

6.2. Implementation of Arithmetic Shape Calculation Interaction with Simulation

Figure 6 shows the variables and functions that are closely related to user input in answering shape questions. The variables in the *CubeVolume.cs* script are divided into length, width and height. Then, based on the answer input box, he will call the function together with the respective variables.

For example, when the user changes the width value, the width function, i.e. void *widthChanged* (string textw), will be called and change the appearance of the width for the following simulation shape. If there is no input, the shape of each type of value will be given to the default value (default value) which is 0.01.


```

public void widthChanged(string textw)
{
    if (textw == "0")
    {
        questionObject.transform.localScale = new Vector3(tempLength, tempHeight, tempWidth);
    }
    else
    {
        float width = float.Parse(textw);
        tempWidth = width;
        questionObject.transform.localScale = new Vector3(tempLength, tempHeight, width);
    }
}
}

```

```

public void widthChanged(string textw)
{
    if (textw == "0")
    {
        questionObject.transform.localScale = new Vector3(tempLength, tempHeight, tempWidth);
    }
    else
    {
        float width = float.Parse(textw);
        tempWidth = width;
        questionObject.transform.localScale = new Vector3(tempLength, tempHeight, width);
    }
}
}

```

```

public void widthChanged(string textw)
{
    if (textw == "0")
    {
        questionObject.transform.localScale = new Vector3(tempLength, tempHeight, tempWidth);
    }
    else
    {
        float width = float.Parse(textw);
        tempWidth = width;
        questionObject.transform.localScale = new Vector3(tempLength, tempHeight, width);
    }
}
}

```

Figure 6. Coding Simulation Calculations for Rectangular Shapes.

6.3. Implementation of Calculation for Calculation Display for Area and Volume.

Based on Figure 7, when the user places the answer value in one of the answer fields provided, the *calculation()* function is called to identify whether the answer value is a long, high or wide value. If only one answer value is given from the three answer fields, the calculation of area and volume is not taken into account. However, if only two answer values are given from any of the filled answer fields, the surface area will be calculated. If all the answer values are entered, the overall calculation of the surface area and volume of the shape is used. At the end of the function, the answer to the calculation made will be displayed on the calculation interface.

```

void calculation(float length, float height, float width)
{
    if (length < 1 && height >= 1 && width >= 1)
    {
        area = height * width;
        volume = 0 * height * width;
        surfaceAreaUI.SetActive(false);
    }
    else if (height < 1 && length >= 1 && width >= 1)
    {
        area = length * width;
        volume = length * 0 * width;
        surfaceAreaUI.SetActive(false);
    }
    else if (width < 1 && length >= 1 && height >= 1)
    {
        area = length * height;
        volume = length * height * 0;
        surfaceAreaUI.SetActive(false);
    }
    else if (length >= 1 && height >= 1 && width >= 1)
    {
        float surfaceAreaValue = ((height * length) * 2) + ((width * length) * 2) + ((height * width) * 2);
        area = surfaceAreaValue;
        volume = length * height * width;
        surfaceAreaUI.SetActive(true);
    }
    else if (length < 1 && height < 1 && width < 1)
    {
        area = 0f;
        volume = 0f;
    }
    else if ((length < 1 && height < 1 && width >= 1) || (height < 1 && width < 1 && length >= 1) || (width < 1 && length < 1 && height >= 1))
    {
        area = 0f;
        volume = 0f;
    }
    else
        wrongQuestion();

    areaValueText.text = area.ToString();
    volumeValueText.text = volume.ToString();
}

```

Figure 7. Coding for area calculations and volumes for rectangular shapes.

7. Assessment Results

This study has gathered the target users for math teaching aids software in terms of shape, and the study was conducted at ABIM Primary and Secondary School (SERI) and Secondary School (SEMI) in Kampung Sungai Ramal Dalam. However, due to time constraints and the coronavirus impact, the government has announced the Movement Control Order (PKP), the study has been carried out to gain access to only one school. The results have been formed in graph, and the 15 respondents were asked to answer the questionnaire.

Figure 8 shows the eight respondents have satisfied with the software in term of easy to use with the percentage of 53.3%. However, four respondents gave a slightly satisfied rating with 26.7% and 3 respondents gave a neutral rating with a percentage of 20%.

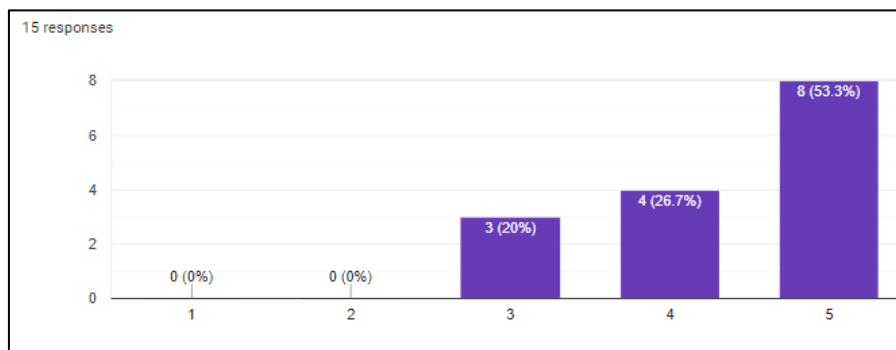


Figure 8. The user responds for easy to learn when using Shape Lab software.

Figure 9 below shows the simulation is suitable for learning. Ten respondents gave a satisfied rating with a percentage of 66.7%. Meanwhile, four respondents gave a slightly satisfied rating while three respondents give a neutral rating, with a percentage of 26.7% and 20% respectively.

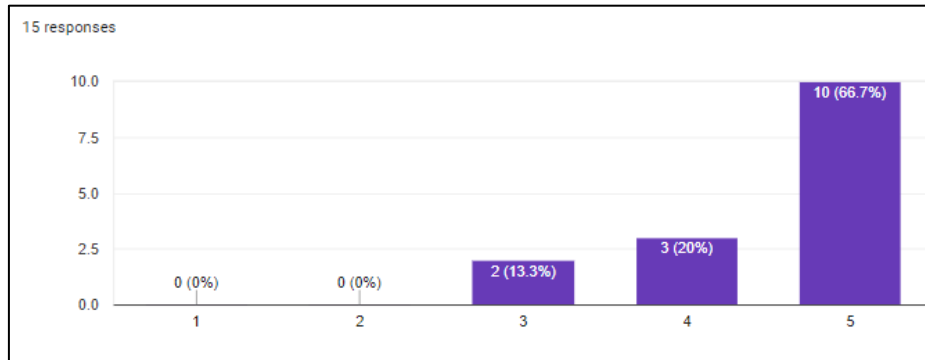


Figure 9. Suitability of simulations used in Shape Lab software.

Finally, Figure 10 shows nine respondents gave satisfied rating with the software in term of ease of use with the percentage of 60%. Three respondents which are 20% of all of the respondents gave a slightly satisfied rating, and two respondents gave neutral rating with a percentage of 13.3%.

The evaluation of Shape Lab software showed positive feedback. Most users choose the strongly agree option for each question indicating that most users agree with the possibility of learning quickly when using the math teaching aid software in terms of shape, Shape Lab. Also, most users find that the simulations provided in the Shape Lab software are appropriate and can give the user a quick exposure of the shape.

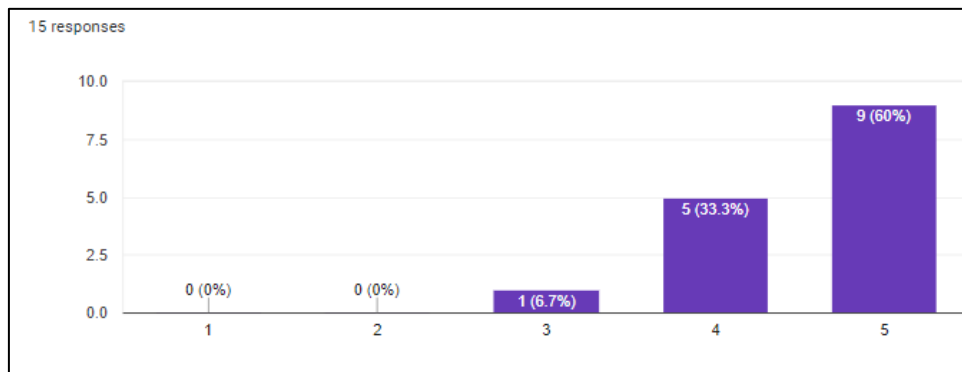


Figure 10. Ease of use when the user works with Shape Lab software.

This software will be tested using black-box testing, and user evaluation to test the effectiveness of mathematics teaching aids software on the target users, PT3 students.

The results for the black-box testing as presented in Table 4, to check the user feedback on the functionality of the application. The verification of the value of the given answers and the calculation of calculations for each type of shape.

Table 4. Black-box testing results in Shape Lab software.

Item	Description	Expected Results	Actual Results
1	The Play button is pressed to start the software.	Page scenes are converted to game scenes	✓
2	The WASD key is pressed to move	Based on the pressed keyboard keys, it will move forward (W), back (S), left (A) and right (D)	✓
3	Move the mouse when in a game scene	Mouse movement allows the player character to look around	✓
4	Approach the question mark symbol	Game guides will be displayed if nearby.	The first symbol indicates the level ✓ The second symbol shows how to answer the question ✓
5	Approaches shape questions based on the level of player being.	A question interaction message will be displayed to indicate the player can answer the shape question when close enough.	All shape questions in Shape Lab software ✓
6	Press the E key when close enough to the question.	Displays questions based on shapes close to the player.	✓ (This interaction can only be made if there is no input from another key.)

8. Conclusion

The aims of this project to developed the application to learned mathematics in terms of shape for secondary school students PT3, *Pentaksiran Tingkatan Tiga* (PT3) 16], successfully achieved. The learning and information is transformed into attractive and interactive using graphical visualization, which is help the students learning journey most easier and enhance the students understanding.

Acknowledgement

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