3D Geometric Shape and Colors Interactive Learning Media using Raspberry Pi, OpenCV, and TensorFlow Lite

M. F. Wicaksono [a,*], M. D. Rahmatya [b]

[a] Department of Computer Engineering, Universitas Komputer Indonesia, Jl. Dipati Ukur 112-116, Bandung, Indonesia
[b] Department of Infomatics Management, Universitas Komputer Indonesia, Jl. Dipati Ukur 112-116, Bandung, Indonesia
Corresponding author: *mfajarw@email.unikom.ac.id

Abstract—**This study aims to create learning media for 3D geometric shapes and colors for early childhood. Early childhood can enter 3D objects into the device. Then, the device will mention and explain the shape and color of the object in question. As a contribution, this research provides a brief introduction and learning related to geometric shapes for early childhood. The method used is experimental. The hardware components of this system are Raspberry Pi 3, RPi Camera, PIR Sensor, 3.5inch LCD, and Speaker. Python, OpenCV, and TensorFlow Lite are used from the software side. OpenCV is used to detect colors. TensorFlow Lite is used to detect the shape of geometric objects. In this study, the model used is a custom model specifically for TensorFlow Lite, which was trained through Google Colab. This media has a learning mode and a question mode. In learning mode, early childhood only needs to insert objects into the learning media and will get information in the form of images and sounds related to the object. In question mode, the learning media will provide instructions and questions to enter objects with a specific color. After that, the learning media will determine whether the answer is right or wrong and give the score. The results of tests that cover both modes reach a success percentage of 100%, where this learning media can recognize and explain every shape and color of objects in both modes.**

Keywords— **3D geometric; Raspberry Pi; OpenCV; TensorFlow Lite; learning media.**

I. INTRODUCTION

This research aims to create learning media for 3D geometric shapes using the Raspberry Pi for early childhood. This must be done because it follows students' learning interests, called extrinsic interest [1]. This type of interest is required to support and complement intrinsic interest. With extrinsic interest, students acknowledge and identify an activity's value and find something that matches the interests and core values given[2]. A study also states that this can be improved and achieved by utilizing information technology and various media[3]. This interest needs to be maintained and improved because it directly relates to motivation, effort, and development[4]. So, in this study, an interactive learning media was made regarding learning the shape and color of 3D objects.

Many studies related to learning media for geometry have been carried out. In 2019, a research made a geometry learning media[5]. However, the geometry learning media required supporting applications to display the slide shows, the quizzes displayed were still static, and the shapes introduced were limited to 2D shapes. Furthermore, another study created a geometry learning media that utilized augmented reality technology[6] and achieved its goal. However, its technology was a limitation because not all children have the devices to run the application.

Subsequent research in 2019 also made learning applications using augmented reality technology specifically for the Android and iOS platforms[7]. However, the need for devices with high specifications cannot be owned by everyone, especially school children who are still at an early age. This is because the device needed is relatively expensive, such as laptops, PCs, or smartphones. In addition, it should be noted that a study states the effects of using augmented reality, where there will be a combination of virtual and real visuals for students that may cause confusion and difficulty navigating between reality and fantasy[8]. Another study in 2020 made educational games about geometry learning[9]. However, this study only focuses on geometric shapes without explaining these forms.

Based on the explanation above, it can be concluded that learning media related to pre-existing geometric shapes

requires relatively expensive devices, especially for augmented reality. Of course, this is the main limitation in terms of use. A study also mentions another limit regarding the ease of user interaction with augmented reality. The ease of user interaction with augmented reality is influenced by age, gender, and experience with augmented reality [10], [11]. On the other hand, the limitations from a technical point of view are the small screen display size, color brightness that will affect implementation, development costs, and considerable computing power[12]. Then apart from these things, one of the studies only focuses on games and requires smartphones. Therefore, it is necessary to have a geometry learning media that is affordable and easy to use but still able to provide learning related to it without sacrificing the essence of education, namely introducing geometric shapes.

In this research, an interactive learning media can introduce 3D geometric objects equipped with learning modes and question modes. The object's shape in this study is limited to 5 forms (cube, cuboid, pyramid, sphere, octagonal) and colors (red, green, blue, orange, yellow) for each object. In learning mode, the learning media can recognize, name, and explain the shape and color of a 3D geometric object entered by the child into this learning media. In question modes, this learning media will ask questions and ask the child to place an object with the right shape and color into this learning media, which, in the end this learning media will determine whether the answer is right or wrong. If the answer is correct, the learning media will sound the correct answer and move on to the next question.

Meanwhile, if the answer is wrong, this learning media repeats the question. If the answer delivered is still wrong up to 3 times, then this learning media will provide the correct answer both in image and sound form. After that, the learning media will continue to the next question, repeat this process until the last question, and give the number of points for the correct and incorrect answer.

From the explanation above, the excess and drawback of this research can be explained. The excess of this research is that this interactive learning media does not require expensive devices, is easy to use, and all early childhood children in school can use it. The drawback of this research is that the object's shape is limited to five shapes and colors. Regardless of the excess and drawbacks of this learning media, this research contributes. One of its contributions is to educational needs. This learning media can be used in early childhood education to introduce 3D geometric shapes and colors as a step of extrinsic motivation.

II. MATERIALS AND METHODS

The method used in this study is an experimental method that involves diverse experiments [13]. Diverse experiments were carried out to get the desired results following the initial goal of making learning media that can recognize, mention, and explain the shapes and colors of 3D geometric objects for early childhood. Several stages of the process of this method can be described as shown in Fig. 1.

A. Study of Literature

At this stage, a study of related previous studies was held out as sufficiently as a search for supporting theories related to the devices that will be needed and used. Mainly, one of the

results of this stage is the difference between this research and previous studies. Previous studies, especially in 2019, have used augmented reality technology [6], [7]. From an economic point of view, the devices used require relatively costly devices, so not all users can use them, and in other studies, the focus is on puzzle games only [9].
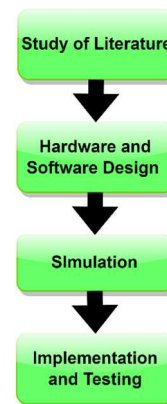

Fig. 1 The flow of research conducted using experimental methods

In 2020, many other studies created learning media about this geometric shape. One of them is research that makes geometry learning media using augmented reality technology [14]. The researcher in that study also wrote down and acknowledged that many students had difficulties using the technology. Another study in 2020 also produced augmented reality learning media that did not have a question mode to measure students' understanding of geometric shapes [15]. In addition to these two studies, other studies in 2020 that produced augmented reality learning media used markers to run their applications [16]. However, the marker did not represent the 3D geometric shapes being studied, which could confuse students.

In 2020, There was also research using web-based applications [17]. However, the main drawback of web-based applications was the large number of computer devices and high bandwidth costs for the application used on each device. Those weaknesses related to this study were demonstrated in research in 2020[18].

In general, it can be said that previous studies required relatively large development costs and expensive devices. From an economic point of view, this is a limitation to using this technology because not all students can afford the required equipment. In addition, the difference in the understanding level of users' ability to use the technology is an undeniable limitation. On the other side, several studies did not have the question mode to measure students' abilities independently. Meanwhile, one study only focused on puzzle games.

B. Hardware and Software Design

This section describes the design of the hardware and software. This hardware design includes block diagram, schematic, and mechanical designs. The software design contains the steps to create a TensorFlow Lite model on Google Colab and the program algorithm of the learning media made. The shape of the block diagram of this learning media is shown in Fig. 2.
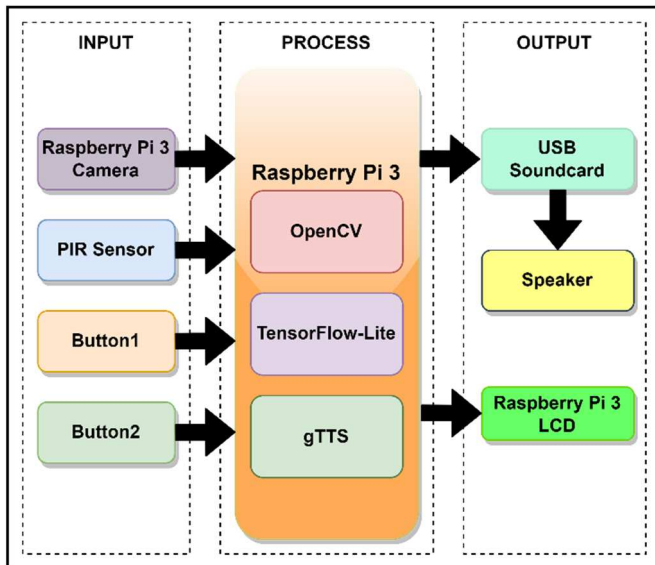
Fig. 2 Block diagram of 3D geometric shapes and colors interactive learning media

Based on the block diagram, it can be explained that there are three main parts, particularly the input, process, and output sections. The input section includes the Raspberry Pi 3 Camera, PIR sensor, button, and button2. In the process section, there is a Raspberry Pi 3 as the primary brain of this system, and it contains OpenCV, TensorFlow Lite, and gTTS. There is a Raspberry Pi 3 LCD, USB Soundcard, and Speaker on the output.

In this study, the Raspberry Pi 3B was used. Raspberry Pi 3B is functioning as a mini-PC. It is supported with a GPIO port of 40 pins to interact with the outside world [19]. In other words, the Raspberry Pi 3B controls and monitors. In terms of random access memory, this type of Raspberry Pi has 1GB of RAM[20]. Button1 and Button2 are used to select the mode. Button1 selects learning mode, while Button2 selects question mode. The HC-SR501 PIR sensor module is used to detect movement when early childhood inserts objects into the learning media. The sensor module is commonly used to detect human movement[21]–[23]. The digital value form is the type of output generated from this module, where when it detects motion, it will issue a logic HIGH[21], [24]. This sensor module requires an input voltage of 5V DC to work[25]. In this case, the input voltage is obtained from the Raspberry Pi. When any motion is detected, the Raspberry Pi will start taking pictures from the camera. The camera used is Raspberry Pi Camera V2. The Sony IMX219 module camera has an 8MP image and video FPS of 200FPS[26]–[28].

The image successfully captured through the camera will then be processed on the Raspberry Pi for shape recognition and color recognition. The object recognition process uses the TensorFlow library specifically for the Raspberry Pi, namely TensorFlow Lite. This open-source library can be used for computing cases, especially machine intelligence, and processed using data flow graphs [29], [30]. TensorFlow allows us to do the model training process quickly and has a fast compilation time. Another advantage of TensorFlow is that it is cross-platform and has a Python API [31], [32], so it fits the case of this study. After the object's shape has been recognized, the recognition results will be stored first into a variable and continued in the color recognition process. The

color recognition process uses OpenCV. OpenCV is an open-source computer vision library focusing on real-time applications [33], [34]. OpenCV has valuable tools for analyzing and processing images [35], [36]. Based on this, OpenCV is appropriate to be used in this case. The results of color recognition with OpenCV will be saved to a separate variable, which will then proceed to the output process in the form of sound related to the shape and color of objects.

To produce sound, the Google Text to Speech (gTTS) library is used in the program. gTTS is a library that can convert text into sound form [37]. The conversion results in the form of sound will be issued through the speaker. Furthermore, specifically for the LCD, it will only actively issue images of geometric shapes on the problem model only when the child has answered incorrectly three times. The LCD used in this study is a 3.5-inch LCD specifically for the Raspberry Pi. The LCD used has a resolution of 480x320 pixels[38]. After getting a suitable block diagram for this learning media, the next step is to make a schematic design that describes the shape of the electronic circuit of this learning media. The schematic form of this learning media is shown in Fig. 3.
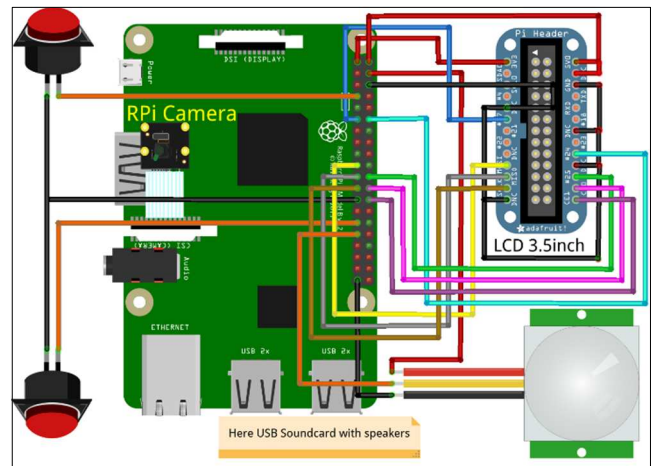

Fig. 3 Electronic schematic of 3D geometric shapes and colors interactive learning media

From Fig. 3 it can be explained that the learning mode and question mode buttons are connected to GPIO4 and GPIO5 using GPIO digital mode. The camera used is connected to the Raspberry Pi's CSI port. The output of the HC-SR501 PIR sensor will be read via the GPIO6 pin. The sound output from this device will be sent via a USB Soundcard and forwarded to the speakers. For display, a special Raspberry Pi LCD is used. It is connected via SPI pins and GPIO7, GPIO17, GPIO18, and GPIO25 pins.
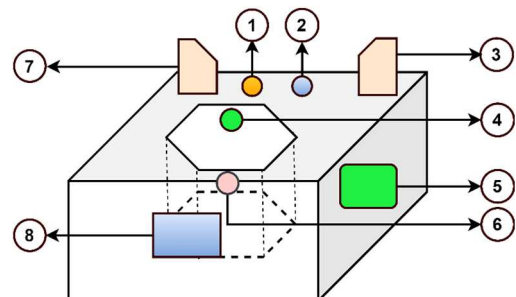

Fig. 4 Design of the placement of each component on the learning media

The following is a description of the component names of each numbering section in Fig. 4:
1. Learning mode button
2. Question mode button
3. Left speaker
4. Raspberry Pi Camera
5. Raspberry PI 3B
6. PIR Sensor
7. Right Speaker
8. Raspberry Pi LCD

After completing the design of the required circuits, the next step is to design the mechanical form and determine the placement of all the components. An image of the design of this learning media is shown in Fig. 4.

The following design section is software design which includes modeling and algorithm design. The model creation process used TensorFlow Lite specifically for the Raspberry Pi. Making this model using Google Colab. The procedures for making this model include:
1. Installing the packages needed for TensorFlow Lite Model Maker on Google Colab, as shown in Fig. 5.

```
!pip install -q tflite-model-maker
!pip install -q tflite-support
```

| 577 kB 5.0 MB/s
| 1.1 MB 53.9 MB/s
| 238 kB 72.2 MB/s
| 60.9 MB 1.1 MB/s
| 1.3 MB 45.5 MB/s
| 840 kB 53.7 MB/s
| 77 kB 6.7 MB/s
| 87 kB 7.2 MB/s
| 128 kB 64.9 MB/s
| 10.9 MB 53.3 MB/s
| 3.4 MB 52.3 MB/s
| 25.3 MB 20.3 MB/s
| 497.9 MB 34 kB/s
| 352 kB 71.6 MB/s
| 462 kB 61.3 MB/s
| 1.4 MB 55.9 MB/s
| 5.8 MB 54.9 MB/s
| 40 kB 6.2 MB/s
| 216 kB 76.8 MB/s
Building wheel for fire (setup.py) ... done

Fig. 5 Installing Model Maker on Google Colab

2. Import the required packages for the modeling process in Google Colab using several commands as shown in Fig. 6.

```
Import the required packages.

import numpy as np
import os

from tflite_model_maker.config import ExportFormat, QuantizationConfig
from tflite_model_maker import model_spec
from tflite_model_maker import object_detector

from tflite_support import metadata

import tensorflow as tf
assert tf.__version__.startswith('2')

tf.get_logger().setLevel('ERROR')
from absl import logging
logging.set_verbosity(logging.ERROR)
```

Fig. 6 Importing the packages

3. Taking custom datasets. The created dataset contains 300 images of 3D geometric shapes, including pictures of cubes, blocks, spheres, pyramids, and octagonal with various colors. 80% of the data is train data, and 20% is test data, as shown in Fig. 7.

```
train_data = object_detector.DataLoader.from_pascal_voc(
    'geoshapes/train',
    'geoshapes/train',
    ['pyramid', 'cube','cuboid','sphere','octagonal']
)

val_data = object_detector.DataLoader.from_pascal_voc(
    'geoshapes/validate',
    'geoshapes/validate',
    ['pyramid', 'cube','cuboid','sphere','octagonal']
)
```

Fig. 7 Load the dataset

4. Choosing the model architecture to be used which in this case uses EfficientDet-Lite0 as shown in Fig. 8.

```
spec = model_spec.get('efficientdet_lite0')
```

Fig. 8 Choosing model architecture

5. Conducting data training processes. Here was used epoch 20, which means the training process takes 20 times as shown in Fig 9.

```
model = object_detector.create(train_data=train_data,
                               model_spec=spec,
                               batch_size=4,
                               train_whole_model=True,
                               epochs=20,
                               validation_data=val_data)

Epoch 1/20
31/31 [==============================] - 51s 387ms/step
Epoch 2/20
31/31 [==============================] - 10s 320ms/step
Epoch 3/20
31/31 [==============================] - 10s 336ms/step
Epoch 4/20
31/31 [==============================] - 10s 315ms/step
Epoch 5/20
```

Fig. 9 The process of training data

6. Conducting model evaluation processes to evaluate the model against new data. The AP value was obtained at 0.747406 in this process as shown in Fig. 10.

```
model.evaluate(val_data)

2/2 [==============================] - 32s 16s/step

{'AP': 0.747406,
 'AP50': 0.89338773,
 'AP75': 0.88822985,
 'APs': -1.0,
 'APm': -1.0,
 'APl': 0.7474078,
 'ARmax1': 0.7552857,
 'ARmax10': 0.863416,
 'ARmax100': 0.863416,
 'ARs': -1.0,
 'ARm': -1.0,
 'ARl': 0.863416,
 'AP_/pyramid': 0.8690946,
 'AP_/cube': 0.8089433,
 'AP_/cuboid': 0.6653182,
 'AP_/sphere': 0.7796752,
 'AP_/octagonal': 0.61399883}
```

Fig. 10 The process of Model Evaluate

7. Exporting the trained object into TensorFlow Lite format. The results of the process of making this model with the TensorFlow Lite extension are shown in Fig. 11.
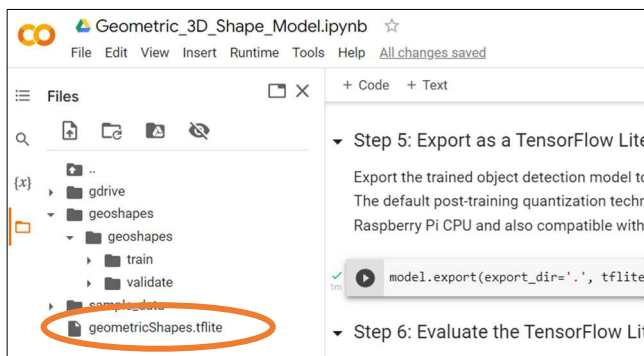

Fig. 11 Results of the TensorFlow Lite model creation in Google Colab

After getting the model required to be implemented and used in the program, the next step is to create an algorithm for this learning media. This algorithm is written in text form to describe the flow of the program that runs on the learning media that is built. Here is the algorithm:

1. Start
2. Initialize variables and I/O pins
3. Select mode
4. Is the learning mode button selected?
5. If yes, then:
   a. Do the learning mode process.
   b. Is the PIR sensor a HIGH value?
   c. If not, then return to point 5. b.
   d. If yes then proceed to point 5. e.
   e. Take a picture using the camera
   f. Converts the image from BGR to RGB to suit the needs of the TensorFlow Lite model
   g. Create a Tensor image object using the Vision API library from TensorFlow Lite
   h. Detect the shape of the object using the created model and save it to the shape variable
   i. Mark the shape of a recognized object
   j. Detect the color of the object using openCV and save the result to the color variable
   k. Are shape variables and color variables non-empty?
   l. If yes, then:
      • Make sounds related to shapes, colors, and short explanations using gTTS
      • Go back to the first section of the learning mode process at point 5. a.
   m. If not, repeat the process of capturing the image again, starting from point 5. e.
6. If not, then proceed to point 7
7. Is the question mode button selected?
8. If yes, then:
   a. Do the question mode process. Randomize the questions.
   b. Read question number 1
   c. Is the PIR sensor a HIGH value?
      • If yes, return to 8. c.
      • If not, then carry out the process of recognizing the shape and color of objects as in point 5.e. up to 5. l.

   d. Do early childhood place objects with colors that match the correct questions/answers?
      • If yes, vote correct and, continue to the next question and increment the correct answer variable.
      • Otherwise, cast a wrong vote and increment the wrong answer variable to the corresponding number.
   e. Has it been wrong three times?
      • If yes, display the shape of the object in question on the LCD and explain, then move on to the next question
      • if not, cast a correct vote, move on to the next question, and increment the correct answer variable.
   f. Repeat the process 8. a to 8.d. until question number 10
   g. Vote regarding the number of correct and incorrect answers and vote "thank you for studying and keep on increasing your enthusiasm for learning" using gTTS.
9. If not return to point 3.

C. Simulation

The simulation process is carried out by simulating the program that has been made. This simulation is done through the terminal. This simulation includes program lines related to learning mode and question mode functions, sensor functions, image capture and recognition, LCD, and voice. The terminal generates text that corresponds to the type of function simulation performed.

D. Implementation and Testing

In this section, an overall test is carried out following the objectives and scenarios of the program where the learning media can recognize the shape and color of 3D geometric objects both in learning mode and in question mode.

III. RESULTS AND DISCUSSION

The physical form of the learning media and some of the 3D objects made based on the initial objectives and all stages of the research are shown in Fig. 12.

Fig. 12 Learning media of 3D geometric shapes and colors

After all hardware and software have been successfully created, the next step is to carry out the testing process. The testing process is divided into several parts, namely the mode

testing process, the PIR sensor testing process for image capture activation, the testing process of learning mode that includes geometric object recognition and color and sound output testing, and the last testing is question mode. Tests on the select mode were done to test the function of switching modes between learning and question mode. Testing in select mode is carried out by the author. The author also tests the capture image features, which involve PIR sensors and cameras. Early childhood was involved in the learning and question-mode testing. In learning mode testing, testing is carried out to ensure that the tool can recognize the shape and color of objects and provide explanations according to the shape of the identified object.

A. Testing Select Mode

In this section, a mode selection test is carried out to see whether this learning media can immediately switch modes when a mode button is pressed. This mode switched immediately because the reading of the digital value on this pin uses the interrupt method. The testing for this select mode was carried out ten times. The results of the testing modes are shown in Table 1.

TABLE I
TEST RESULTS OF MODES FUNCTION

Test No.	Button1	Button2	Learning Mode	Question Mode	Status
1	LOW	HIGH	√	-	valid
2	LOW	HIGH	√	-	valid
3	HIGH	LOW	-	√	valid
4	HIGH	HIGH	-	-	valid
5	HIGH	LOW	-	√	valid
6	LOW	HIGH	√	-	valid
7	LOW	HIGH	√	-	valid
8	HIGH	LOW	-	√	valid
9	LOW	HIGH	√	-	valid
10	HIGH	LOW	-	√	valid

The test results presented in Table 1 show that the learning media has been able to switch from learning mode to question mode and vice versa. The mode switching is indicated by a logical value of LOW that is read from Button1 (GPIO4) and Button2 (GPIO5).

B. Testing PIR and Camera Function

The following process is the image capture function testing involving the HC-SR501 PIR sensor and Raspberry Pi camera. This is intended to ensure that the camera actively captures pictures when the PIR sensor detects an early child's hand inserting a 3D geometric object into the learning media. The results of testing this function are shown in Table 2.

TABLE II
TEST RESULTS OF PIR DETECTION AND CAPTURE IMAGE

Test No.	PIR	Camera	Status
1	LOW	-	valid
2	HIGH	√	valid
3	HIGH	√	valid
4	LOW	-	valid
5	LOW	-	valid
6	HIGH	√	valid
7	LOW	-	valid
8	HIGH	√	valid
9	LOW	-	valid
10	HIGH	√	valid

Based on the results of the tests that have been carried out regarding the PIR and Camera function shown in table 2, it can be said that the testing of the image capture process is successfully carried out when the PIR sensor output is HIGH. All the result tests in this hardware function test have shown that this learning media has been running according to the scenario of the program created.

C. Testing Learning Mode

The testing process continues in the next section, namely the detection of the shape of geometric objects and their colors as part of the learning mode. At the same time, sound output testing is also carried out to ensure that the learning media produces an explication according to the object's shape that has been recognized. The testing process is done by debugging and displaying the results on the monitor screen to ensure that objects and colors are recognized successfully. The object's shapes and colors recognized will appear on the screen and be bordered with the form and color description above the border. Some of the display images during testing related to the shape of these objects and colors are shown in Fig. 13.
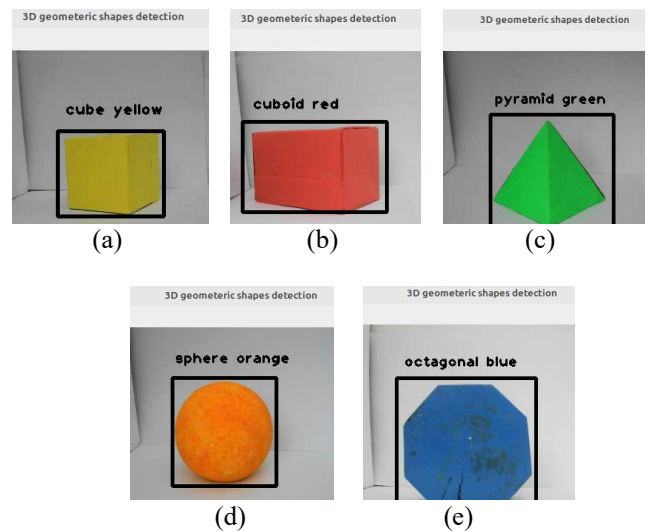

(a) (b) (c)

(d) (e)

Fig. 13 Sample objects and colors that have been recognized: (a) yellow cube; (b) red cuboid; (c) green pyramid; (d) orange sphere; (e) blue octagonal

From Fig. 13 it can be seen that objects and colors have been recognized successfully. The testing process related to the object's shape and color recognition is done ten times for each object. All the results of the tests related to shape, color, and sound are shown in Table 3.

TABLE III
TEST RESULTS OF SHAPE AND COLOR DETECTION AND SOUND

3D Geometric Object	Output Shape and Color Detected										Explanation with gTTS
	1	2	3	4	5	6	7	8	9	10	
Red Cube	√	√	√	√	√	√	√	√	√	√	√
Green Cube	√	√	√	√	√	√	√	√	√	√	√
Blue Cube	√	√	√	√	√	√	√	√	√	√	√
Orange Cube	√	√	√	√	√	√	√	√	√	√	√
Yellow Cube	√	√	√	√	√	√	√	√	√	√	√
Red Cuboid	√	√	√	√	√	√	√	√	√	√	√
Green Cuboid	√	√	√	√	√	√	√	√	√	√	√

3D Geometric Object	Output Shape and Color Detected										Explanation with gTTS
	1	2	3	4	5	6	7	8	9	10	
Blue Cuboid	√	√	√	√	√	√	√	√	√	√	√
Orange Cuboid	√	√	√	√	√	√	√	√	√	√	√
Yellow Cuboid	√	√	√	√	√	√	√	√	√	√	√
Red Pyramid	√	√	√	√	√	√	√	√	√	√	√
Green Pyramid	√	√	√	√	√	√	√	√	√	√	√
Blue Pyramid	√	√	√	√	√	√	√	√	√	√	√
Orange Pyramid	√	√	√	√	√	√	√	√	√	√	√
Yellow Pyramid	√	√	√	√	√	√	√	√	√	√	√
Red Sphere	√	√	√	√	√	√	√	√	√	√	√
Green Sphere	√	√	√	√	√	√	√	√	√	√	√
Blue Sphere	√	√	√	√	√	√	√	√	√	√	√
Orange Sphere	√	√	√	√	√	√	√	√	√	√	√
Yellow Sphere	√	√	√	√	√	√	√	√	√	√	√
Red Octagonal	√	√	√	√	√	√	√	√	√	√	√
Green Octagonal	√	√	√	√	√	√	√	√	√	√	√
Blue Octagonal	√	√	√	√	√	√	√	√	√	√	√
Orange Octagonal	√	√	√	√	√	√	√	√	√	√	√
Yellow Octagonal	√	√	√	√	√	√	√	√	√	√	√

The test results presented in Table 3 are part of the learning mode. Table 3 shows that the learning media successfully recognizes all shapes and colors of geometric objects like cubes, cuboids, pyramids, spheres, and octagonal. In addition, learning media can produce output in the form of sound regarding shapes, colors, and a brief explanation of the object's shape recognized.

D. Testing Question Mode

The next test is a question mode test. The learning media gives ten questions to early childhood that are taken randomly from 25 inquiries stored in it. This test is intended to see if this question mode is running according to the program scenario that has been made. If the answer is correct, the process will continue to the next question. However, if the answer is incorrect, the learning media will repeat the question up to three times. The test results for this mode are shown in Table 4.

TABLE IV
TEST RESULTS OF QUESTION MODE

Test No.	Question	Answer		Repeat Question	Sound and LCD	Status
		T	F			
1	Which is the red cuboid? please select and enter into the tool	√	-	-	-	valid
2	Which is the red cube? please select and enter into the tool	-	√	√	-	valid
3	Which is the red cube? please select and enter into the tool	√	-	-	-	valid
4	Which is the orange sphere? please select and enter into the tool	√	-	-	-	valid
5	Which is the orange pyramid? please select and enter into the tool	-		√	-	valid
6	Which is the orange pyramid? please select and enter into the tool	-		√	-	valid
7	Which is the orange pyramid? please select and enter into the tool	-		√	√	valid
8	Which is the blue octagonal? please select and enter into the tool		√	-	-	valid
9	Which is the yellow cube? please select and enter into the tool		√	-	-	valid
10	Which is the red sphere? please select and enter into the tool		√	-	-	valid

The test results in Table 3 show that when early childhood puts the correct 3D geometric object into the learning media, the learning media will continue the process to the next question. This can be seen in questions points 1 to 2, questions point 3 to 4, and questions point 8 to 10.

Furthermore, at question points 2 to 3, it appears that the learning media succeeded in repeating the question when the answer was incorrect. The following case is when there are three wrong answers, which can be seen in question points 5 to 7. The learning media successfully repeats the question up to 3 times and then gives the correct answer through sound and images on the LCD. From the results of this test, it can be concluded that this learning media can randomize the questions given, determine correct and incorrect answers, repeat questions up to 3 times when the answers are wrong, and provide the correct answers in the form of sound and images.

From all the test results shown in Table 1, Table 2, Table 3, and Table 4, it can be concluded that this learning media has achieved the desired goals and is running well according to the program scenario that has been made. The learning media can run in learning and question mode. The learning media can recognize all shapes and colors of 3D objects entered into the learning media. It can be used by every child easily because it only needs to insert objects into the learning media. In other words, the child will be invited to move and act to learn. This is in line with the related statement to avoid the combination of virtual and real visuals that might confuse children[8]. In other studies, it requires equipment that is expensive not only in development but also equipment and will be tricky to use by early childhood [6], [7], [14]–[16], and one of the studies only focuses on puzzle games and requires a smartphone [9].

IV. Conclusion

The 3D geometric shape and colors interactive learning media has been running well with a 100% success percentage, as seen from all the tests that have been carried out following the initial objectives and program scenarios, where this learning media can already run learning mode and question mode. In addition, this learning media has recognized the shape of 3D geometric objects and their colors. The learning media has also succeeded in providing a sound output related to the shape of the object, the color, and a brief explanation of the object. For further development, other geometric shapes and colors may be added.

References

[1] M. F. Wicaksono, Syahrul, M. D. Rahmatya, and M. A. F. Rahman, "Raspberry Pi-Based Solar System Learning Media," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 879, no. 1, pp. 1–7, 2020, doi: 10.1088/1757-899X/879/1/012022.

[2] R. M. Ryan and E. L. Deci, "Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions," *Contemp. Educ. Psychol.*, vol. 61, p. 101860, 2020, doi: 10.1016/j.cedpsych.2020.101860.

[3] L. Sun and C. E. Pan, "Effects of the Application of Information Technology to E-Book Learning on Learning Motivation and Effectiveness," *Front. Psychol.*, vol. 12, no. September, pp. 1–5, 2021, doi: 10.3389/fpsyg.2021.752303.

[4] P. Y. Lin, C. S. Chai, M. S. Y. Jong, Y. Dai, Y. Guo, and J. Qin, "Modeling the structural relationship among primary students' motivation to learn artificial intelligence," *Comput. Educ. Artif. Intell.*, vol. 2, no. October 2020, p. 100006, 2021, doi: 10.1016/j.caeai.2020.100006.

[5] D. T. Wahyuningtyas, N. Yuniasih, N. R. Sesanti, and M. N. Hudha, "Two-dimensional interactive media for fourth grade students," in *Journal of Physics: Conference Series*, 2019, vol. 1318, no. 1. doi: 10.1088/1742-6596/1318/1/012003.

[6] D. Rohendi, S. Septian, and H. Sutarno, "The Use of Geometry Learning Media Based on Augmented Reality for Junior High School Students," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 306, no. 1, 2018, doi: 10.1088/1757-899X/306/1/012029.

[7] S. Gargrish, A. Mantri, and D. P. Kaur, "Augmented reality-based learning environment to enhance teaching-learning experience in geometry education," in *Procedia Computer Science*, 2020, vol. 172, no. 2019, pp. 1039–1046. doi: 10.1016/j.procs.2020.05.152.

[8] T. Khan, K. Johnston, and J. Ophoff, "The Impact of an Augmented Reality Application on Learning Motivation of Students," *Adv. Human-Computer Interact.*, vol. 2019, p. 7208494, 2019, doi: 10.1155/2019/7208494.

[9] T. Ridwan, E. Hidayat, R. Hikmawan, R. Andrian, and A. Yasin, "Research on the Development of Edu Games as Learning Media for Geometry and Arithmetic in Elementary School Children," *Int. Conf. Elem. Educ.*, vol. 3, no. November, pp. 57–61, 2020, [Online]. Available: http://proceedings2.upi.edu/index.php/icee/article/view/1443

[10] N. M. Alzahrani, "Augmented Reality: A Systematic Review of Its Benefits and Challenges in E-learning Contexts," *Applied Sciences*, vol. 10, no. 16. 2020. doi: 10.3390/app10165660.

[11] R. O. Virata and J. D. L. Castro, "Augmented Reality in Science Classroom: Perceived Effects in Education, Visualization and Information Processing," in *Proceedings of the 10th International Conference on E-Education, E-Business, E-Management and E-Learning*, 2019, pp. 85–92. doi: 10.1145/3306500.3306556.

[12] R. Lovreglio and M. Kinateder, "Augmented reality for pedestrian evacuation research: Promises and limitations," *Saf. Sci.*, vol. 128, p. 104750, 2020, doi: 10.1016/j.ssci.2020.104750.

[13] H. Hidayat, N. S. Hasibuan, and F. Wicaksono, "Design And Implementation Of Electronic Examination Device For Improving The Blind Students' Comfort," *J. Eng. Sci. Technol.*, vol. 16, no. 1, pp. 807–815, 2021, [Online]. Available: https://jestec.taylors.edu.my/V16Issue1.htm.

[14] M. F. Amir, N. Fediyanto, H. E. Rudyanto, D. S. Nur Afifah, and H. S. Tortop, "Elementary students' perceptions of 3D metric: A cross-sectional study," *Heliyon*, vol. 6, no. 6, p. e04052, 2020, doi: 10.1016/j.heliyon.2020.e04052.

[15] D. Rohendi and Y. Wihardi, "Learning Three-Dimensional Shapes in Geometry Using Mobile-Based Augmented Reality," *Int. J. Interact. Mob. Technol.*, vol. 14, no. 09 SE-Papers, pp. 48–60, Jun. 2020, doi: 10.3991/ijim.v14i09.13035.

[16] U. Mulbar, Alimuddin, Rahmadani, and Adhar, "Using Augmented Reality Media in Three-Dimensional Geometric Shape Material," *J. Phys. Conf. Ser.*, vol. 1899, p. 12160, May 2021, doi: 10.1088/1742-6596/1899/1/012160.

[17] S. Sumarwati, H. Fitriyani, F. M. Azhar Setiaji, M. Hasril Amiruddin, and S. Afiat Jalil, "Developing Mathematics Learning Media Based on E-Learning using Moodle on Geometry Subject to Improve Students' Higher Order Thinking Skills," *Int. J. Interact. Mob. Technol.*, vol. 14, no. 04 SE-Papers, pp. 182–191, Mar. 2020, doi: 10.3991/ijim.v14i04.12731.

[18] M. D. Abdulrahaman *et al.*, "Multimedia tools in the teaching and learning processes: A systematic review," *Heliyon*, vol. 6, no. 11, p. e05312, 2020, doi: 10.1016/j.heliyon.2020.e05312.

[19] J. Sobota, M. Goubej, J. Königsmarková, and M. Čech, "Raspberry Pi-based HIL simulators for control education," *IFAC-PapersOnLine*, vol. 52, no. 9, pp. 68–73, 2019, doi: 10.1016/j.ifacol.2019.08.126.

[20] V. Chauhan, M. Patel, S. Tanwar, S. Tyagi, and N. Kumar, "IoT Enabled real-Time urban transport management system," *Comput. Electr. Eng.*, vol. 86, pp. 1–18, 2020, doi: 10.1016/j.compeleceng.2020.106746.

[21] M. Murad, O. Bayat, and H. M. Marhoon, "Design and implementation of a smart home system with two levels of security based on IoT technology," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 21, no. 1, pp. 546–557, 2021, doi: 10.11591/ijeecs.v21.i1.pp546-557.

[22] S. Bin Saleh *et al.*, "Design of Smart Home Security System using Object Recognition and PIR Sensor," *Energy Build.*, vol. 135, no. 1, pp. 465–472, 2020, doi: 10.1016/j.procs.2018.08.198.

[23] M. F. Wicaksono, M. D. Rahmatya, and - Ilham, "IoT Implementation for Server Room Security Monitoring Using Telegram API," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 12, no. 5, pp. 1931–1937, 2022, doi: 10.18517/ijaseit.12.5.13922.

[24] A. Murad, O. Bayat, and H. M. Marhoon, "Implementation of rover tank firefighting robot for closed areas based on arduino microcontroller," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 21, no. 1, pp. 56–63, 2021, doi: 10.11591/ijeecs.v21.i1.pp56-63.

[25] B. Alathari, M. F. Kadhim, S. Al-Khammasi, and N. S. Ali, "A framework implementation of surveillance tracking system based on pir motion sensors," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 13, no. 1, pp. 235–242, 2019, doi: 10.11591/ijeecs.v13.i1.pp235-242.

[26] T. Gambo, E. E. Omizegba, and A. B. Ba'ams, "Real-Time Video Display System in Articulated Vehicle for Road Safety Enhancement," *Int. J. Sci. Eng. Appl.*, 2019.

[27] X. Mouy *et al.*, "FishCam: A low-cost open source autonomous camera for aquatic research," *HardwareX*, vol. 8, p. e00110, 2020, doi: 10.1016/j.ohx.2020.e00110.

[28] K. Miikki *et al.*, "An open-source camera system for experimental measurements," *SoftwareX*, vol. 14, p. 100688, 2021, doi: 10.1016/j.softx.2021.100688.

[29] M. Liu and D. Grana, "Accelerating geostatistical seismic inversion using TensorFlow: A heterogeneous distributed deep learning framework," *Comput. Geosci.*, vol. 124, no. Maret 2019, pp. 37–45, 2019.

[30] B. Varshini, H. Yogesh, S. D. Pasha, M. Suhail, V. Madhumitha, and A. Sasi, "IoT-Enabled smart doors for monitoring body temperature and face mask detection," *Glob. Transitions Proc.*, vol. 2, no. 2, pp. 246–254, 2021, doi: 10.1016/j.gltp.2021.08.071.

[31] N. Hussain *et al.*, "Application of deep learning to detect Lamb's quarters (Chenopodium album L.) in potato fields of Atlantic Canada," *Comput. Electron. Agric.*, vol. 182, no. February, p. 106040, 2021, doi: 10.1016/j.compag.2021.106040.

[32] M. Amo-Boateng, N. Ekow Nkwa Sey, A. Ampah Amproche, and M. Kyereh Domfeh, "Instance segmentation scheme for roofs in rural areas based on Mask R-CNN," *Egypt. J. Remote Sens. Sp. Sci.*, vol. 25, no. 2, pp. 569–577, 2022, doi: 10.1016/j.ejrs.2022.03.017.

[33] G. Anand and A. K. Kumawat, "Object detection and position tracking in real time using Raspberry Pi," *Mater. Today Proc.*, vol. 47, pp. 3221–3226, 2021, doi: 10.1016/j.matpr.2021.06.437.

[34] S. Sivkov *et al.*, "The algorithm development for operation of a computer vision system via the OpenCV library," *Procedia Comput. Sci.*, vol. 169, no. 2019, pp. 662–667, 2020, doi: 10.1016/j.procs.2020.02.193.

[35] M. Qasaimeh *et al.*, "Benchmarking vision kernels and neural network inference accelerators on embedded platforms," *J. Syst. Archit.*, vol. 113, p. 101896, 2021, doi: 10.1016/j.sysarc.2020.101896.

[36] A. Issac, H. Yadav, G. Rains, and J. M. Velni, "Dimensionality Reduction of High-throughput Phenotyping Data in Cotton Fields," *IFAC-PapersOnLine*, vol. 55, no. 32, pp. 153–158, 2022, doi: 10.1016/j.ifacol.2022.11.131.

[37] V. P. Revelli, G. Sharma, and S. Kiruthika devi, "Automate Extraction of Braille Text to Speech From an Image," *Adv. Eng. Softw.*, vol. 172, p. 103180, 2022, doi: 10.1016/j.advengsoft.2022.103180.

[38] A. Fanariotis, F. Andriopoulou, T. Orphanoudakis, and I. Politis, "An embedded framework enabling access of elderly and disabled persons to IP-based emergency communications," *Microprocess. Microsyst.*, vol. 68, pp. 74–83, 2019, doi: 10.1016/j.micpro.2019.05.006.