

# The Development of Multimedia Courseware of Lines and Planes in 3-Dimension: an Application of van Hiele's Model

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**Abstract:** *With the advent of computer technology, the role of visualization in Mathematics education has become an area of current research interest. This paper is inspired by and utilizes the van Hiele's levels for teaching and learning Lines and Planes in 3 Dimensions. Based on an early study, students have been identified of having problems in visualizing figures. In an attempt to overcome this problem, a multimedia courseware was developed based on a framework that utilizes van Hiele's Geometric model for visualizing 3D models. This paper also points out the features of van Hiele's model and shows that they are also characteristics of the proposed levels of Lines and Planes in 3D. The tools used for developing the courseware are 3DS Max 7 and Macromedia Director MX. A conceptual framework was developed based on van Hiele's model. In order to gauge the effectiveness of the courseware as an aid for visualizing 3D models, a testing was conducted with 60 high school students aged 14 years old. The groups are divided into control and experimental. The results have shown that the students have demonstrated the ability to visualize and enhance their understanding on the topic after using the courseware.*

## 1. Introduction

With the advent of computer technology, the role of visualization in Mathematics education has become an area of current research interest [1]. Most of the researchers have emphasized on the importance of visualization and visual reasoning for learning mathematics [2]. These visual representations can enhance students learning concepts. An early study has shown that visualization problem is considered serious among students whereby 14 out of 31 form four students in a secondary school in Malaysia have been identified as having difficulties in visualizing 3D model [3]. Although the study covers a small student population in a selected school in Malaysia, but the high percentage of affected students could indicate a serious problem on the larger population. The problem that most of the students have is the inability to visualize the exact point of intersection between a line and a plane, or between two planes. This problem can be related to their inability to understand geometric aspect of a diagram or a shape.

The advantages of multimedia courseware in assisting students in their learning process have been well established. Thus, it is believed that the combination of multimedia courseware and the wide perspective that the visualization of 3-Dimension objects could provide a possible solution for the visualization problem. The van Hiele's model for Geometric model has been considered for the courseware development since it deals with visualization aspect in understanding shapes in mathematics.

In this work, we have developed a multimedia courseware for visualizing 3D models by utilizing the van Hiele's model for teaching and learning Lines and Planes in 3 Dimensions.

## **2. Related Work**

### **2.1 Multimedia Courseware**

The term media reflects a single element, while multimedia is the combination of more than one media elements namely text, image, sound, video and animation [3, 4, 5]. In a multimedia courseware which is an aided learning application, the media elements are combined together with the learning content. According to [6], a multimedia courseware can actually stimulate the learners' mind as well as motivate the learner in the learning process.

### **2.2 3-Dimensions Model**

An object or image consists of many shapes and dimensions. Real objects that are observable in daily life are a combination of length, width and height dimensions. In the context of computer graphic, an image can be presented either in 2-dimensional or 3-dimensional forms. A 3-dimensional image provides a better representation of a figure or diagram because it reflects the reality of that object which can be seen from three different perspectives [7]. In order to produce a 3-D image or model, 3-D modeling process is used [8]. The output of the 3-D model produced from the modeling process is very precise since it is a combination of various entities and elements [8]. A 3-D model will also improve the visual interaction and the children's ability to understand a complicated figure or drawing [9].

### **2.3 The Van Hiele's Model**

In the study conducted earlier, nearly 50% of the students were identified as having problem in visualizing 2D model in order to identify the point of intersection between a line and a plane, or between two planes [1]. The identified problem is actually related to human spatial visualization of shapes which are not clearly specified or hidden [10, 11].

The students' problem in learning geometry or shapes was the motivation for Pierre van Hiele and his wife, Dina van Hiele-Geldof to introduce the van Hiele model of geometric thinking in 1986 [12]. According to [13], there are five van Hiele levels which are:

- visual level (Level 1): The students will identify the shapes according to the appearance, recognizing them as visual Gestalts using the visual prototype.
- Descriptive and Analytic level (Level 2): Students will have to reason about the concepts of the parts and attributes.
- Abstract and relational level (Level 3): Students need to relate the properties and appreciate the role of the general definitions.
- Formal deductive level (Level 4): Students will understand the axioms or theories and construct their understanding.
- Mathematically rigorous level (Level 5): Students will need to compare the various theories and study various shape.

There are various levels of formats in this theory since there are many arguments on the differences in human geometric understanding especially when it is related to children [12]. In this work, the use of 3D model and multimedia courseware aims to support the students' thinking at the visual level. The students' ability to master the first level is very important because they will not be able to progress to the higher level if they have not acquired the previous geometric understanding [14]. [13] also describes that the expected learners' understanding for visual level is when the

students are able to recognize the shapes and some of its properties. Hence, the multimedia courseware with 3D models which we have developed must be able to provide the learners with the appropriate instruction and sufficient information in order to assist visualization. Among the strategies that have been suggested by [13]:

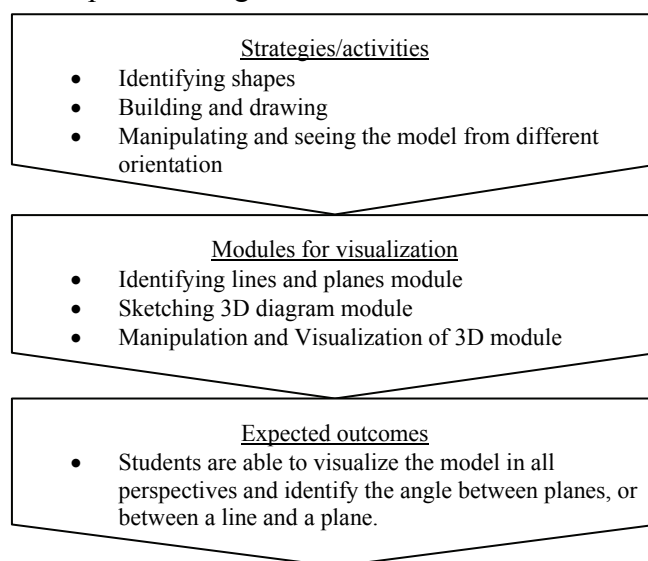
- sorting, identifying, and describing shapes.
- Manipulating physical models.
- Seeing different sizes and orientations of the same shape as to distinguish characteristics of a shape and the features that are not relevant.
- Building, drawing, making, constructing, putting together, taking apart shapes.

### 3. Methodology

The methodologies for developing the multimedia courseware with 3D model for Lines and Planes are discussed in this section. The method employed begins with the development of a conceptual framework based on van Hiele model, followed by the development of the framework. Finally the courseware was developed.

#### 3.1 Conceptual Framework based on van Hiele Model

The conceptual framework of the courseware consists of strategies, modules for visualization and expected outcomes. This is depicted in Figure 3.1.



**Figure 3.1** Framework

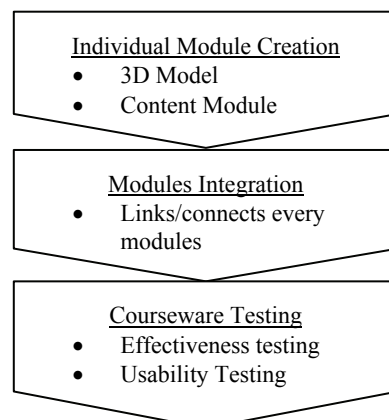
#### 3.2 Development of Courseware Modules

ADDIE model has been adopted as the flow process guideline for the entire development of the courseware. The process of creating the modules for the multimedia courseware for Lines and Planes in 3-Dimension has been done during the development phase.

For creating the 3D model, Autodesk 3DS Max 7 is used as the 3D modeling tool. The reason for using the older version of 3DS Max is because the tool is compatible with Macromedia Director MX. The process of creating the 3D model begins with the identification of shape or figure that is going to be created. All the figures or 3D models are based on the form four Mathematics syllabus and other references. Once the shape or object has been identified, the figure will be drawn using the tools provided in 3DS Max 7 under 'Object Type' option such as Box, Plane and Pyramid. Several elements or object created will be combined or grouped together to produce the desired 3D figure.

Then, 'Material Editor' is used to create a transparent material for the main object. The reason for making the main object transparent is to make the other properties such as lines and planes visible to the users. The final stage in creating the 3D model is to 'export' the object into a Macromedia Director MX compatible format which is '.w3d'. The ready '.w3d' file now can be imported from the Macromedia Director MX. The 3D models are then organized and programmed to enable rotation in response to user's clicking and dragging of the mouse. The Director's library for 3D actor being used in this context is 'Drag Model to Rotate'. The reason for using rotation is to make the 3D model visible from all angles for assisting the learners to recognize the shape and also to identify the other required information, specifically the angle between a line and a plane, or between two planes.

The other development processes, apart from 3D modeling, are done in Macromedia Director MX as the multimedia authoring application in this project. All texts are created within Director itself, but some other media such as images, video, sounds and 3D models are imported from outside. All media elements are combined to create interactive modules for this courseware for Lines and Planes in 3-Dimension. The final stage in completing the multimedia courseware for Lines and Planes in 3-Dimension is the insertion of voice instruction that will guide, instruct and explain the content and scenes in the courseware. Figure 3.2 shows the development process of the courseware.



**Figure 3.2** Development Process Flow

### 3.3 Courseware Testing

60 high school students aged 14years old are involved in the study. They are divided into two: control and experimental groups. The control group will go through the traditional learning method while the experimental group was taught using the courseware. After completing 3 hours and 20 minutes of the whole lesson (time allocated to cover the topic), the students were given a set of

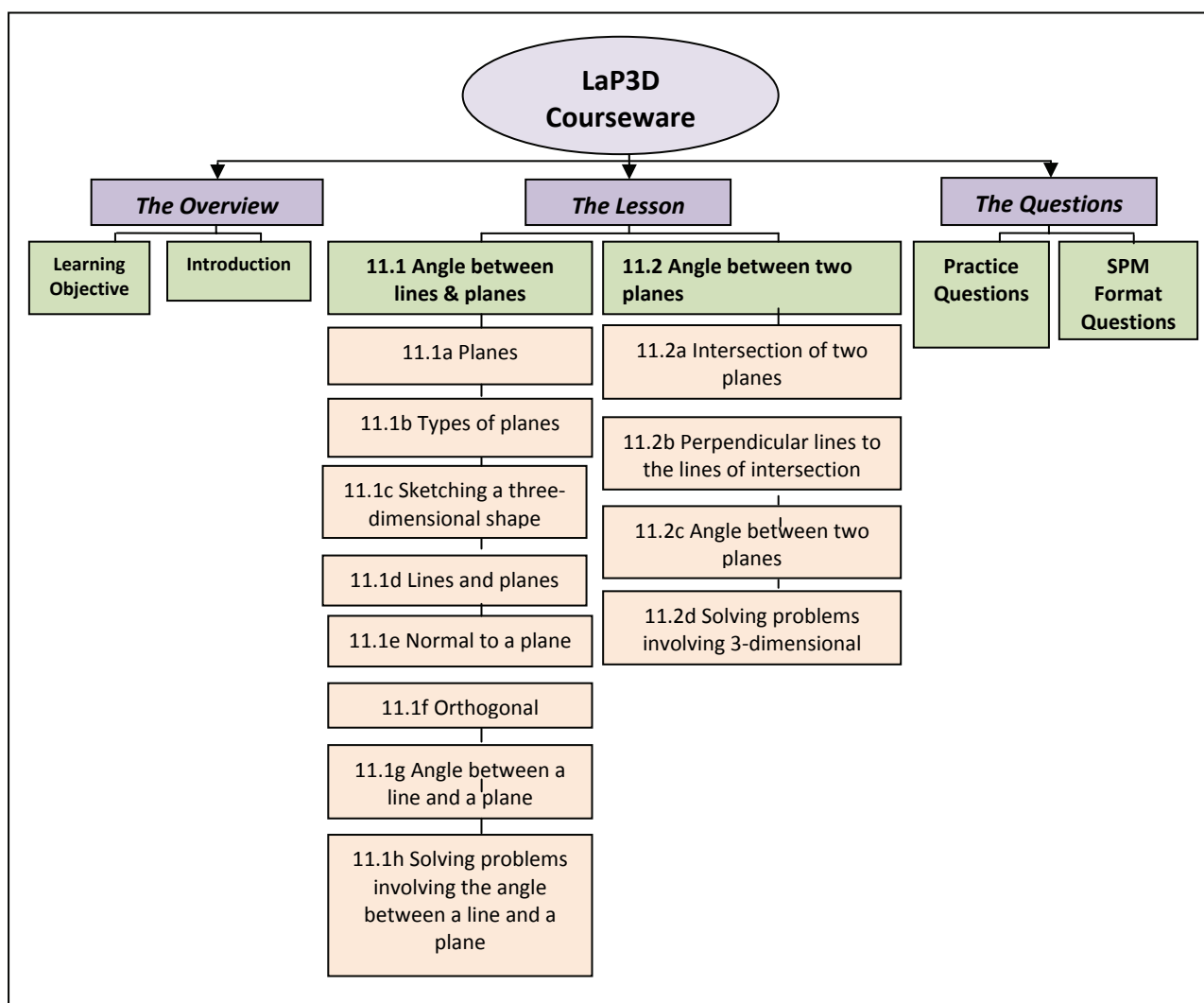
questions based on the topic. A pre and post test questions were given to both groups in order to gauge the effectiveness of the courseware as an aid for visualizing 3D models.

## 4. Result and Discussions

The prototype multimedia courseware was tested on visualizing the 3D models using the van Hiele model and the results are presented and discussed in this section.

### 4.1 The Multimedia Courseware for Lines and Planes in 3-Dimension

There are 3 modules in the courseware for Lines and Planes in 3-Dimension (LaP3D) namely 'The Overview', 'The Lesson' and 'The Questions'. The 'Overview' consists of learning objectives and introduction. In 'The Lesson Module', users will be introduced to the whole content of Lines and Planes in 3D. Meanwhile in 'The Questions' module, related practice exercises and questions according to SPM examination format are provided to test the students' understanding of the topic. The modules are illustrated in Figure 4.1.



**Figure 4.1** Courseware Modules

## 4.2 Interfaces of LaP3D

The courseware begins with the Home page as the initial screen before the users or learners started their lesson. This is shown in Figure 4.2. The Home screen is divided into three main sections which are 'The Overview', 'The Lesson' and 'The Question'; where each section is linked to its specific module. The first section, 'The Overview', presents the objective of learning Lines and Planes in 3-Dimension as well as a general introduction to the lesson. The main content of the Lines and Planes in 3-Dimension topic is presented in 'The Lesson' section. In 'The Lesson' section, students will go through various interactive modules which are created to give the students understanding in this topic as well as to assist them in developing their visualization ability. The third section, 'The Questions', is developed to assess the students' understanding of the topic and also acts as an enrichment module that supports the content delivered in the previous section.

Figure 4.3 shows the screen of the 'Identifying Plane' module. This module is created to give information to the students regarding the type of planes which indirectly comply with the first strategy towards visualization. The ability to identify plane is one of the requirements for the students to surpass the first level of van Hiele model [11]. Figure 4.4 shows the 'Sketching 3-dimensional Shape' module. The module will guide the students in drawing a 3-dimension object. This module can increase the learners' understanding of geometric aspect of shapes by observing the steps for sketching a figure as animated in the courseware. The descriptive and analytic levels of van Hiele model have been applied in this module where students will have to apply the reasoning concepts of 3D shapes.

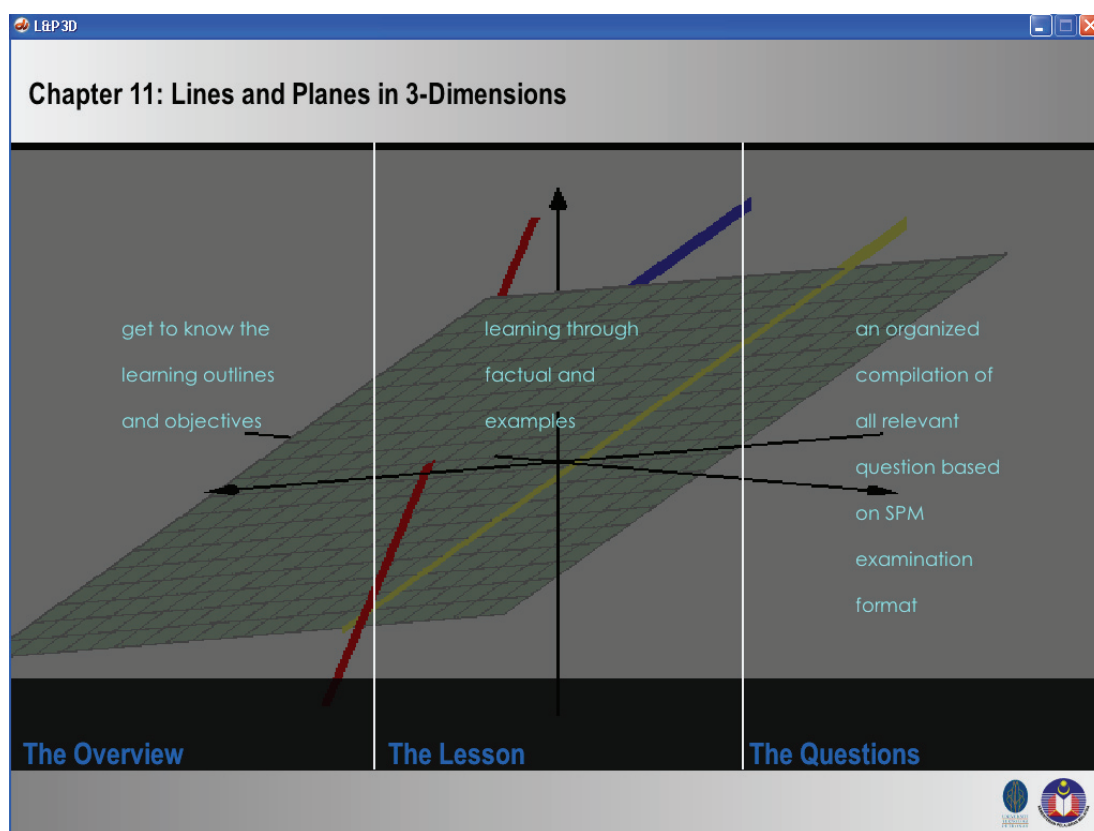


Figure 4.2 Home page (Main screen)

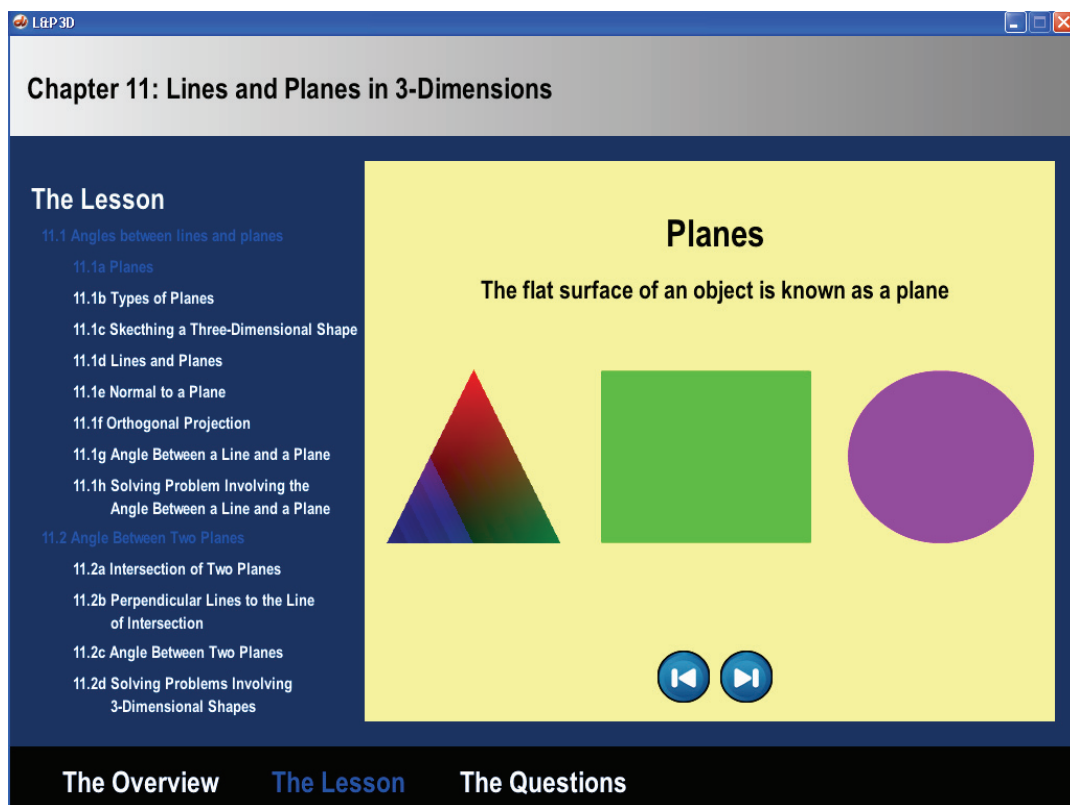


Figure 4.3 Identifying Planes module

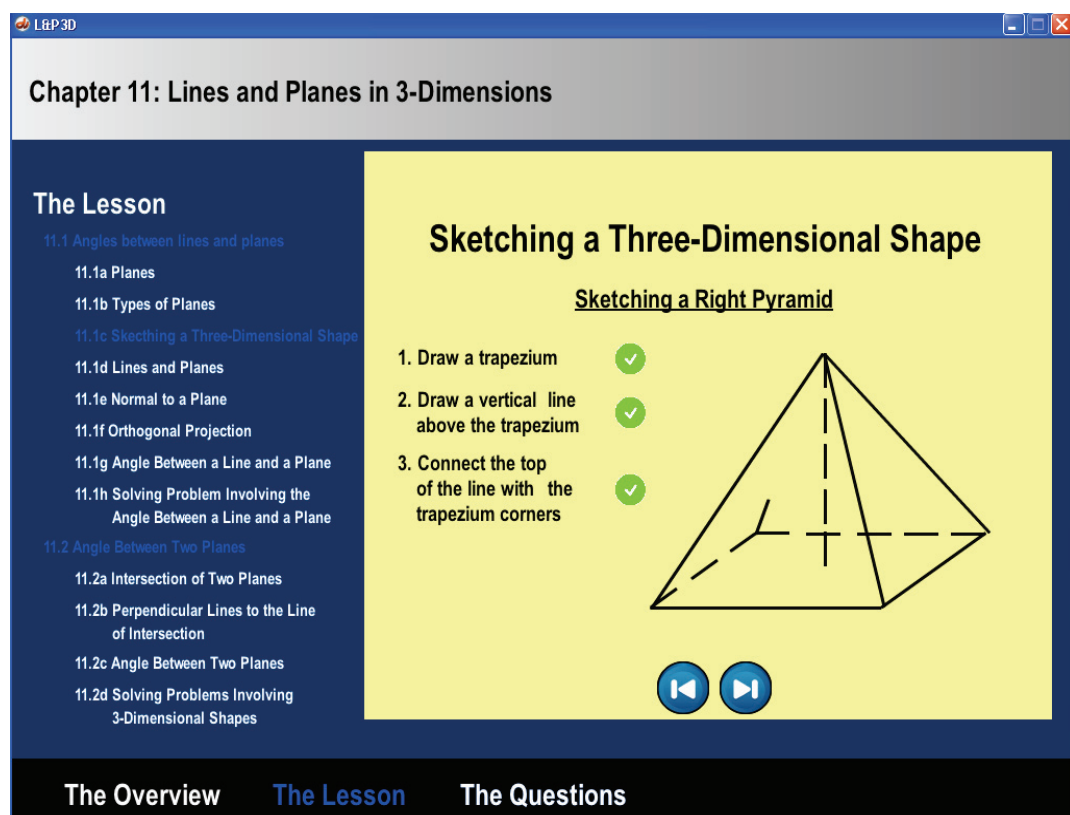
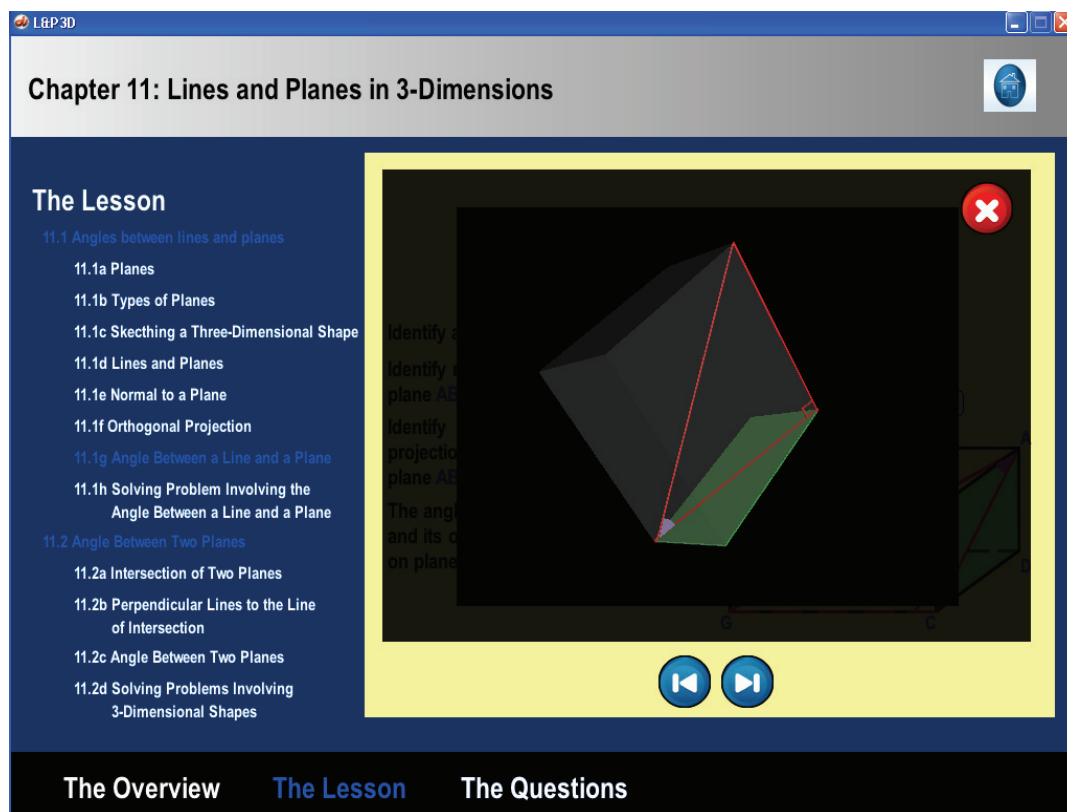


Figure 4.4 Sketching 3-Dimensional shape module

Figure 4.5 shows the 3D model, the module that complies with the third strategy towards visualization which is manipulating and seeing object from different orientation. The 3D model can be rotated when the user clicks the right button. The modules shown in Figure 4.3, Figure 4.4 and Figure 4.5 have been developed according to the conceptual framework developed earlier.



**Figure 4.5** ‘Visualize’ 3D module

## 4.2 Results

These questions have been specifically created to assess the effectiveness of the courseware, in which two levels of the van Hiele model have been applied, in improving students’ visualization of geometric shapes. Table 4.1 shows the students’ average scores for the related modules in the courseware.

From Table 4.1, it is clear that the post-test questions have been created in-line with the topic on Lines and Planes in 3-Dimension and are parallel with the guidelines towards visualization. The average score for the question on identifying lines and planes is 3.27 out of 4, while for the question on identifying and calculating angle between lines and planes, and angle between planes, the average score is 5.27 out of 6. For this kind of question, most of the students were able to correctly identify the angle although some of them were not able to calculate the angle value. This finding is in agreement with the findings by [14] where the 3D diagrams were able to facilitate students’ learning and visualization of the abstract concepts. The result also indicates that the students managed to visualize the figure in the questions, which is the first level of understanding of the van Hiele geometric model.



**Table 4.1** Classification of Students' Score in Post-test

<i>Strategies</i>	<i>Implemented Modules</i>	<i>Question(s) in Post-test</i>	<i>Students' Average Score</i>
<i>Identifying shapes</i>	<i>Identifying lines and planes module (eg. Figure 3)</i>	<i>Question 1-4(4 marks)</i>	3.27
<i>Building and drawing</i>	<i>Sketching 3D diagram module</i>	<i>None</i>	NA
<i>Manipulating and seeing the model from different orientation</i>	<i>Manipulation and Visualization of 3D module (Figure 4.5)</i>	<i>Question 5 and 6. Students were required to identify the line or planes then visualize the position of the angle. Finally, they have to calculate the angle. (6 marks)</i>	5.27

Table 4.2, 4.3 and 4.4 show the results of a t-test on the pre and post test scores and also the increment score between the two groups. From Table 4.2, it shows that there is no significant different between both groups. In other words, their levels are the same. Result from Table 4.3 shows that there is a significant different where the experimental group has performed better than the control group. Table 4.4 has shown that there is a significant different in the incremental score of the test. The results show that there is a significant improvement in students' performance after using the multimedia courseware that indirectly indicates LaP3D courseware can be used as a tool to assist students in visualizing the figures in the topic of Lines and Planes in 3-Dimensions.

**Table 4.2** Independent t-Test for Pre test

Variable	Mean	SD	t-value	Sig. (2 tailed)
Pre-test X <sub>1</sub>	1.3000	1.11880	6.364	0.58
Pre-test X <sub>2</sub>	1.2333	1.00630	6.713	0.58

**Table 4.3** Independent t-test for Post test

Variable	Mean	SD	t-value	Sig. (2 tailed)
Post-test X <sub>1</sub>	6.8000	1.91905	19.408	0.00
Post-test X <sub>2</sub>	8.8333	1.23409	39.205	0.00

**Table 4.4** Independent t-Test for increment score

Variable	Mean	SD	t-value	Sig. (2 tailed)
Increment X <sub>1</sub>	5.5000	2.08029	14.481	0.00
Increment X <sub>2</sub>	7.6000	0.89443	46.540	0.00

## 5. Conclusion

Students' problem in visualizing 3-D objects is a serious problem that must be solved effectively with the right tools and methods. Although van Hiele's model was designed for geometry, the application of van Hiele model can also be applied in enhancing visualization in 3D objects. From this study, the targeted students have demonstrated the ability to visualize and

enhance their understanding on the topic after using the prototype courseware. This might agree with the proverb that a picture is worth than a 1000 words.

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