Using 5E inquiry for learning nested dielectrics objects rendering

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Abstract. Nested dielectrics refer to non-metallic objects which do not conduct electricity modelled within other non-metallic objects. It is a difficult problem to render in this situation, especially transparent objects. In 3D rendering, when nested dielectric objects need different physical rendering properties such as a glass of cola and ice for having realistic results from rendering, it can cause confusion in rendering and results in negative learning effects for students. In this research, we use 5E inquiry to teach nested dielectrics objects rendering. The assignment is given to the students to evaluate their understanding. We divide the rubric score into 3 parts: key concepts in physics of light absorption, refractive index followed by the 3D modelling approach, and finally, applying physics concepts for nested dielectric objects rendering. The results were analysed from students’ scores in each part. It is found that learning with this sequence, 20 percent of students can understand clearly, 68 percent partially understand and 12 percent misunderstand.

1. Introduction

In Shading Lighting and Rendering (SLR) subject, one of the learning units is nested dielectric objects rendering, most dielectric objects are the object that nested in other objects. In 3D rendering, nested dielectrics refer to non-metallic objects modelled within other non-metallic objects which is a difficult problem to render in these situations. For example, we want an accurate rendering result (or crating an image) of modelling a drink in a glass with ice cubes, to render, it needs different refractive index values for all models such as a glass of drink, air bubbles and ice cubes[1].

According to the students’ misconceptions, several of learning activities of learning methods have been promoted to the classes instead of traditional learning, such as application of guided note in lecture [2], peer instruction, 5E inquiry, or interactive lecture demonstrations [3-6] as it could help students achieve their conceptual understanding. One of the learning model which is corresponded to constructivist theory is 5E. 5E is an instructional model that is based on constructivism theory or called inquiry cycle instruction, which is commonly used in science teaching. 5E consists of important steps that are: 1) engagement step, which is to stimulate the interest of students into the learning content 2) exploration, which is a step for students to do various activities to collect learning data/information 3) explanation step, which is the analysis and conclusion from the data/information obtained 4) elaboration step, which is the use of knowledge to connect or explain other relevant knowledge and 5) evaluation, which is the step to assess students in various areas arising from learning management[7].

Continuity in learning the nested dielectrics learning unit has the main point, which nested dielectrics objects need different physical rendering properties. As mentioned, most students have misconceptions and confusion in this learning unit. Thus, in this research, we use the concept of 5E to represent the learning sequence of this learning unit with the guideline from the lecturer in order to improve the
students understanding in nested dielectrics objects and to improve learning and teaching methods in the future.

2. Methodology and learning activities

In the classroom, the learning unit of nested dielectric starts with explaining the topic, the expected learning outcomes and the scope of assessments that will be given to the students after studying. We explain the 5E inquiry steps as follows:

2.1. Engagement

The first step is to stimulate the interest of the students. Some questions are given to the students, for example, “What is nested dielectrics objects?” or “What we have to concern in creating nested dielectrics objects?” Moreover, the famous animation scene will be represent to the students in order to make them interested and want to create a work like that. After that, the lecturer holds the questions and answers with students regarding the questions.

2.2. Exploration

In this step, students carry out activities such as experiments for explore physics concepts of light absorption and refractive index and create 3D models. Then, the lecturer holds the exercise and answers with students regarding the questions.

The lecturer explains that absorption depends on the electromagnetic frequency of the light and object’s nature of atoms. If they are complementary, light is absorbed. If they are not complementary, then the light passes through the object or gets reflected. If a material absorbs light of certain wavelengths, an observer will not see these colour(s) in the reflected light. On the other hand, if certain wavelengths of colour are reflected, these are the colour that the observer will see. For example, leaves contain the pigment chlorophyll, which absorbs blue and red colour of the light and reflects green; therefore, leaves appear green [8]. In order to make students visualize the light absorption more. In figure 1, gummy bears with laser pointer are used [9] for the experiment. When pointing a red laser beam to a red gummy bear, the red laser light passes through it or gets reflected because the red gummy bear does not absorb red colour. Pointing the red laser beam to a green gummy bear cannot make the observer see the reflected colour. When light ray travels through a transparent object, it accumulates tint from the transmission colour according to the distance value. If the light ray hits a non-transparent object, it combines the surface colour with the accumulated tint. In figure 2, the lecturer express students’ understanding of this concept by determining which colour(s) of light will be transmitted and the colour that the paper will appear to an observer [10].

![Figure 1. The activity of light absorption using gummy bears](image1)

![Figure 2. Problems in light absorption in exploration steps and students’ sample answers](image2)
The lecturer explains that light refraction is the bending of the light when it enters a substance into another where its speed is different [11]. With the difference of substance density, it can change the speed of light, causing change of direction. Light refracts whenever it travels at an angle into a substance with a different refractive index. For example, when light travels from air into water, it slows down, causing it to continue to travel at a different angle or direction. To describe how fast light travels through the material, it is defined as refractive index that can be calculate from the formula. For this concept, the experiment using a glass of water, it can be seen that it shows refraction of the arrow image when the light travels through the glass and water as shown in figure 3. As it can be seen that the arrow image were upside down when the observer looks through the glass. The lecturer evaluate the students’ understanding by finding the index of refraction from the formula as shown in figure 4 [12].

![Figure 3](image-url)  
*Figure 3. The activity of light refraction and demonstration using glass and water*

For accurate 3D rendering results, it is important that the model follows certain guidelines and be realized that every object is a solid shape and has volume. In figure 5, the lecturer explains the 3D modelling approach in 3 cases: 1) scale liquid down, the gap between the glass and the liquid is small which make the rendering result does not look realistic 2) coincidental surfaces, the surfaces of both the glass and liquid are sitting on the top of each other which cause the identifying problems between each surface as overlapping artefacts 3) scale liquid up, the scale of the liquid has been increased so that it overlaps the glass geometry which looks better than the liquid appears to touch the glass [12]. After that, the lecturer evaluate the students’ understanding by assigning them to modelling and rendering in 3 cases as described earlier.

![Figure 5](image-url)  
*Figure 5. 3 types of modelling approach in (a) concepts (b) model wireframe and (c) the exercise to evaluate the students’ understanding of 3D modelling approach*
2.3. Explanation
In this step, once the students have sufficient information from exploration step, the lecturer provides opportunities for students to explain the results of their exploration. The main conclusion for students is that transparent objects have no absorption value and the distances that light travels will depend on refractive index. If it is a glass with water and ice, the light transmission is dependent on the refractive index of three substances. The refractive index of water, ice and glass are 1.33, 1.31 and 1.50 respectively. Also students must apply the physics concepts to the 3D model that they created. Technically, the priority of the objects has been involved to the rendering process ordered by the priority number; the number which comes first will render that object first and still has the colour of itself [13], the overall concept of nested dielectrics object as shown in the figure 6.

![Diagram](image)

**Figure 6.** The overall concept of creating nested dielectrics object that students must conclude

2.4. Elaboration
In this step, expanding students’ conceptual understanding by giving practice questions and the knowledge from previous steps. This can help the students connect all the information of nested dielectrics objects. The students will practise analysing other nested dielectrics objects such as a rendering of a fish jar or a double-walled glass.

2.5. Evaluation
In this step, to finally assess the students’ understanding, the assignment will be given to the students as “Please modelise and render a glass of coloured water with an ice cube”. The lecturer divide the assignment into 3 parts; the key concepts in physics of light, the 3D modelling approach, and applying the key concepts in physics to the physical rendering properties for nested dielectrics rendering objects. The rubric scores used to analyze the students understanding in each part [14] are shown in table 1 and the final understanding criteria are shown in table 2.

| Table 1. Rubric score criteria in each part |
|-------------------------------------------|
| No. of part                              | Score | Criteria                                      |
| 1. the key concepts in physics of light   |       |                                               |
|                                          | 3     | Can explain the concepts of absorption and refractive index clearly                                      |
|                                          | 2     | Can explain the concepts of absorption and refractive index but miss some information                |
|                                          | 1     | Cannot explain the concepts of absorption and refractive index                                      |
| 2. 3D modelling approach                 |       |                                               |
|                                          | 3     | Correct modelling approach for all objects (model overlaps each other)                              |
|                                          | 2     | Correct modelling approach for some objects                                                     |
|                                          | 1     | Wrong modelling approach for all objects                                                       |
| 3. applying the key concepts in physics   |       |                                               |
|                                          | 3     | Correct refractive index value and correct priority for all objects                              |
|                                          | 2     | Correct refractive index value and correct priority for some objects                            |
|                                          | 1     | Wrong refractive index value and wrong priority for all objects                                 |
Table 2. Criteria to decide an understanding of nested dielectrics objects

| Performance       | Criteria                                                                 |
|-------------------|---------------------------------------------------------------------------|
| Understand        | Student can do correctly in every step and have the right rendering result with the overall score more than 7 points |
| Partially understand | Student can do correctly in some steps and have the right rendering result with the overall score between 5-7 points |
| Misunderstand     | Student can do correctly in some steps but have the wrong rendering result with the overall score less than 5 points |

3. Results and discussions

From the assessment of students’ understanding, we analyse the students’ understanding of nested dielectrics objects from the assignment. Figure 7 shows the understanding percentage of 34 students. 20 percent or 7 students can understand clearly, 68 percent or 24 students partially understand and 12 percent or 3 students misunderstand.

Figure 7. Percentage of students’ understanding

Figure 8 shows a bar chart of students’ understanding grouped by students’ average scores in each part. It is found that the average score of the students that understand clearly is 3.00 points in 2 parts, which means they can do well in the 3D modelling approach part and can apply the physics key concepts to the 3D model properties. Most students have low score in the first part; between 1.00 – 2.71 points as they cannot predict which object will absorb the light more and this confuses the priority setting for rendering in the third part. Therefore, it can be observed that if they have low score in the first part, the score in the third part will be low as well, because these 2 parts are clearly related. Most of the mistakes of the students are their understanding in light absorption. We found that in the Exploration step, the demonstration of light absorption and light refraction can make students see that the object can absorb the light colour(s) and can see the light refraction but they cannot tell which colour will appear to the observer when the object is nested. Alternative learning activities or demonstration may be required to help students correctly and more deeply understand the concepts.

For students who understand, they can predict the light absorption colour result and can define the value of refractive index of glass, solid and ice. Figure 9(a) shows that the ice inside the glass combines water colour, which is orange, with the accumulated tint which the ice color will be light orange. For students who partially understand, in figure 9(b), it can be seen that the ice and the water have the same colour, which is brown, and make the rendering results look unrealistic. For students who do not understand as shown in figure 9(c), the wrong rendering result is from the ice. The colour of the ice is tinted with the water and also the mistake from wrong refraction index, ice color and 3D modelling mistake.
Figure 9. Students’ assignment results compared with the realistic object (a) understand (b) partially understand and (c) misunderstand

4. Conclusion
In conclusion, we use 5E inquiry to teach the nested dielectrics objects, the students are interested and pay attention to the learning unit. We demonstrate the important concepts of nested dielectrics objects by using learning matter from things that can be seen in daily life until the students have enough information. The exploration step is the important step to create the basic important understanding, so the lecturer and the students should pay more attention to this step [15]. This learning method allows students to take action and find knowledge on their own from the experiment in order to classify, distinguish, and connect elements that are relevant to the study [16]. Activities are important in the learning, meaning increasing the activity of students will affect other aspects such as understanding concepts or reducing misconceptions [17]. Providing assignment for students is a way to evaluate their understanding. The teacher-training exercises aim to strengthen students’ self-conceptual understanding. Through the assignment, they will often recall the concepts they learn so they can permanently store them in their memories and can recall again later. In addition to providing practice questions, this stage also encourages the students to conclude their knowledge from the class that has been done [15].

From our findings, the suggestion for the next research would be to find a method or a framework to enhance the students’ understanding and to stimulate their thinking skills in scientific reasoning at the beginning of the class to make the learning method be more efficient.

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