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Teaching the Principle of Sunscreen Material using ZnO, TiO_2, SiO_2, Al_2O_3, and CeO_2 to Elementary School Students

Yusup Maulana[(a)], Wahyu Sopandi [(a)], Asep Kadarohman[(b)], Asep Bayu Dani Nandiyanto [(b)*], Natasha Puspa Dewi[(c)]

[(a)] *Department Elementary Education, Universitas Pendidikan Indonesia, Bandung, Indonesia*
[(b)] *Department Chemistry, Universitas Pendidikan Indonesia, Bandung, Indonesia*
[(c)] *Departemen Sastra Inggris, Universitas Komputer Indonesia, Bandung, Indonesia*

** Corresponding author:*
nandiyanto@upi.edu
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Abstract

This study aims at analyzing the experimental demonstration teaching method using video on elementary school students' science learning outcomes and identifying the principle of sunscreen using various materials against the sun. The principle of sunscreen is taught using photo paper smeared with a light-sensitive liquid. After that, the sunscreen material is dripped on the paper, coated with transparent plastic, exposed to sunlight, and observed for changes. To analyze the physical properties in the morphology of the sunscreen material observations with SEM and XRD. Students' understanding is assessed through a 20-pretest posttest question supported by a learning video, where the research subjects are 23 elementary school students in Indonesia. The results show that the principle of sunscreen material using ZnO, TiO2, SiO2, Al2O3, and CeO2 can keep the light-sensitive paper from changing color after being exposed to sunlight. There was an increase in students' understanding of the principle of sunscreen material after being given a learning video. This study shows and useful for informing the principle of sunscreen using various materials and students' understanding of it.

Keywords: *Sunscreen material, Elementary school, Teaching, Ultraviolet rays*

1. Introduction

UV radiation that is too long on the skin can cause skin diseases such as skin cancer and allergic reactions to light/photoallergy [1]. UV radiation can be divided into UV A, UV B, and UV C. UV C can be absorbed by ozone in the earth's atmosphere. For this reason, most of the sunlight in the environment is divided into UV A (90 - 95%) and UVB (5 - 10%). UV rays can penetrate the layers of the skin depending on the wavelength. UV A has a wavelength of 315 - 400 nm and has the lowest energy; UV B wavelength is 280 - 320 nm, while the UV C wavelength is 100 - 280 nm and has the highest energy. UV A can penetrate the dermis layer. Most of the UV B rays are absorbed by the epidermis, and only a small part reaches the dermis layer. UV A can produce Reactive Oxygen Species that can damage DNA, while DNA can directly absorb UV B. The existence of modifications in the DNA can cause mutations and cancer [2] Sunscreens work by containing an active ingredient that absorbs radiation in the range of 290–400 nm. In most countries, these active ingredients are regulated as cosmetics. Sunscreens are classified as either physical or chemical based on their active ingredient. Sunscreen products combine ingredients in a variety of combinations to produce a product that confers stability and optimal UV protection [3]. In physical sunscreens the active ingredient is an inorganic compound that works by physically reflecting or scattering the UV radiation [4]. In chemical sunscreens the active ingredient is an organic compound that works by absorbing UV radiation and dissipating the energy as heat or light [5]. Physical sunscreen using in this study is ZnO [6], TiO_2 [4], SiO_2 [7], Al_2O_3 [8], and CeO_2 [9]. The cyanotype process can be used for demonstration because it can show changes in the paper after exposure to sunlight. Ultraviolet radiation in the sun can catalyze the changes that occur to change the color in the paper [10]. The sensitizer is an alternative to cyanotype; the sensitizer is commonly used as an 'afdruk' in screen printing; this material is sensitive to ultraviolet rays because the color of the yellow liquid that is applied to photo paper can turn brown after being exposed to sunlight. The principle of sunscreen can be taught to children as a starting point in applying basic life science, which is interesting because of the skin topics in biology, ultraviolet light in physics, and nanoparticles in chemistry. Based on Piaget's theory of intellectual development, elementary school-age children (6-12) years old are in the concrete operational phase, meaning that children have a high curiosity and particular sensitivity in knowledge, skills, awareness, and attitudes [11]. Therefore, the learning process can be done using the experimental demonstration method. The experimental demonstration method is a teaching method by demonstrating items, events, rules, and sequences of activities, either directly through learning media following the material presented and improving student understanding [12-15]. In this study, we used experimental demonstration using video as learning media. There are many reports on applications and studies related to UV, solar, photocatalyst light, including: interpret uv-vis spectrophotometric [16], solar-powered submersible pump system [17], Thin Films for Solar Cells Application [18], conventional solar still [19], Design-Construction of A Solar Cell Energy Water [20], LED grow light driver circuit for indoor strawberry cultures [21], Photodecomposition profile of organic material [22], natural convection in the air gap of a vertical flat plate thermal solar [23] and Bibliometric Analysis Of Titanium Dioxide Nanoparticle Synthesis Research For Photocatalysis [24].

This research novelty is that the material sunscreen we used was besides ZnO and TiO_2, using SiO_2, Al_2O_3, and CeO_2. The sensitizer, alternative cyanotype, is also a novelty in this research for an understanding student in the principle of sunscreen. This study aims at analyzing the experimental demonstration teaching method using video on elementary school students' science learning outcomes and identifying the principle of sunscreen using various materials against the sun. The level of students' understanding is assessed by using 20-pretest-posttest questions. Students are given a pretest to assess their abilities, a learning media in the form of video, and a posttest to reassess student abilities. This research helps inform the result of using various materials sunscreen and students' understanding of it.

2. Materials and Methods

2.1. The making of material

Raw materials used in the experiment were purchased from chemical suppliers in the online market (Tokopedia): ZnO, TiO2, SiO2, Al2O3, CeO2, sensitizer, namely diazol. Other materials from local stores are brushes, photo paper, and sample containers. The water for dissolving the sample comes from the bathroom. Before the experiment, make sure it is in a room not exposed to direct sunlight. The experiment was carried out as follows: Step 1: Prepare photo paper and light-sensitive liquid; Step 2: Dissolve samples of ZnO, TiO2, SiO2, Al2O3, and CeO2 with clean water; Step 3: Apply photo paper with light-sensitive liquid, wait for it to dry; Step 4: Drop each sample liquid and oil on photo paper that has been smeared with light-sensitive liquid; Step 5: Cover it with clear plastic; Step 6: Observe the changes.

2.2. The Physical Properties Analysis

This study tested the sample using Scanning Electron Microscope (SEM) JSM-6360 model and X-Ray Diffraction (XRD) tests. SEM is an electron microscope capable of producing high-resolution images of a sample. SEM is used to see the surface topography of a sample and the size of the sample. The obtained results in a scanning electron micrograph with a three-dimensional shape in the form of a photo. In comparison, XRD is an analytical method used to identify the crystalline phase by determining the lattice structure parameters and obtaining particle size. Detailed information on interpreting XRD, SEM, and FTIR has been reported in several other studies including: calculate crystallite size from x-ray diffraction (XRD) using scherrer method [25], calculate diameter size from electron microscopy images [26], and interpret FTIR spectroscope of organic material [27].

2.3. Teaching Methods

We used experimental demonstration method using video as the learning media. The subject in this study is 23 grade five elementary student in Tangerang, Indonesia. The pretest-posttest is carried out using score scale of 0 (wrong) and 1 (correct). The average score of each question is converted into % and tabulated. The processes for determaining the level of students' understanding is three stages. In the first stage, students were given a 20-questions pretest to determine knowledge about principle of sunscreen. Thereafter, students were given a learning video that includes the explanation of principle sunscreen reflection and absorption UV rays, the making of experiment using various sunscreen material there are ZnO, TiO2, SiO2, Al2O3, and CeO2. Posttest is then given to find out there is an increase in students' understanding. The increase in student learning outcomes is analyzed for each question with a normalized gain score [28] with the formula:

$$g = \frac{\text{posttest score} - \text{pretest score}}{\text{maximum possible score} - \text{pretest score}}$$

The Following table list the interpretation of the effectiveness of the N-gain to measure the efectiveness of learning using video.

Table 1. Category of interpretation of the effectiveness of the N-gain score

Category	Limitation
High	$g > 0.7$
Medium	$0.3 \leq g \leq 0.7$
Low	$g < 0.3$

3. Results and Discussion

3.1. The Physical Properties Analysis with various sunscreen material

Figure 1 shows an SEM image of the particles used for the sunscreen active ingredient experiment. These results suggest that these particles can be used as an experimental material for the principle of sunscreen. The nanostructures of ZnO on the SEM property test images tend to look like nanorods because the temperature and sintering time is perfect. The ZnO powder sample's nanostructure has a good shape structure. Theoretically, the difference in sintering time and temperature will make a difference in the nanostructure of ZnO powder. ZnO is a versatile, functional material with various morphological groups such as nano comes, nanorings, nanohelices, nanosprings, nanobelts, nanowires, nanorods, and nanocages [29]. All these unique nanostructure classifications indicate that ZnO has abundant nanostructures both in terms of structure and properties. SEM results show that the formed TiO_2 particles have almost the same morphology, namely spherical. SEM results of Al_2O_3 are in the form of irregular alumina grains, the results of SEM SiO_2 look like lumps, and some are round in shape with different sizes. In comparison, the state of CeO_2 appears to have a cubic crystal structure of fluorite. Figures 2-6 shows the results of XRD analysis showed the crystallinity characterization of the sunscreen material to identify the crystalline phase in the material by determining the lattice structure parameters and the particle size. The diffraction peaks show a powerful peak intensity, which gives an understanding that the nanopowder sunscreen material used has high crystallinity

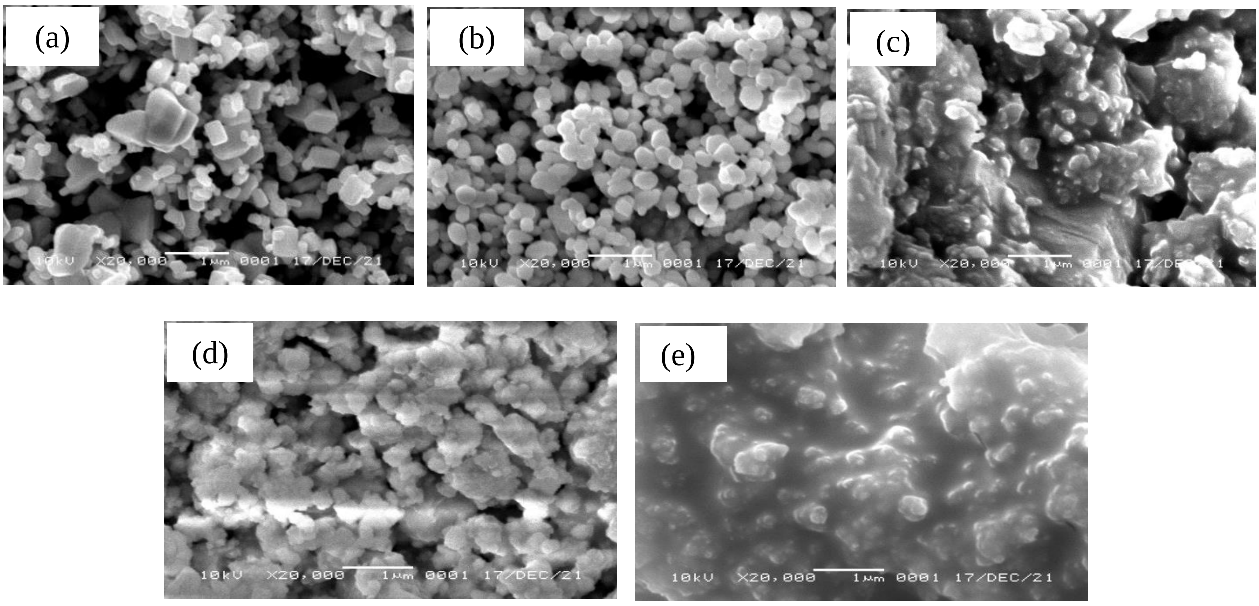

Figure 1. Investigation of material structuralization using SEM 20.000x (a) ZnO, (b) TiO_2, (c) Al_2O_3. (d) CeO_2, and (e) SiO_2

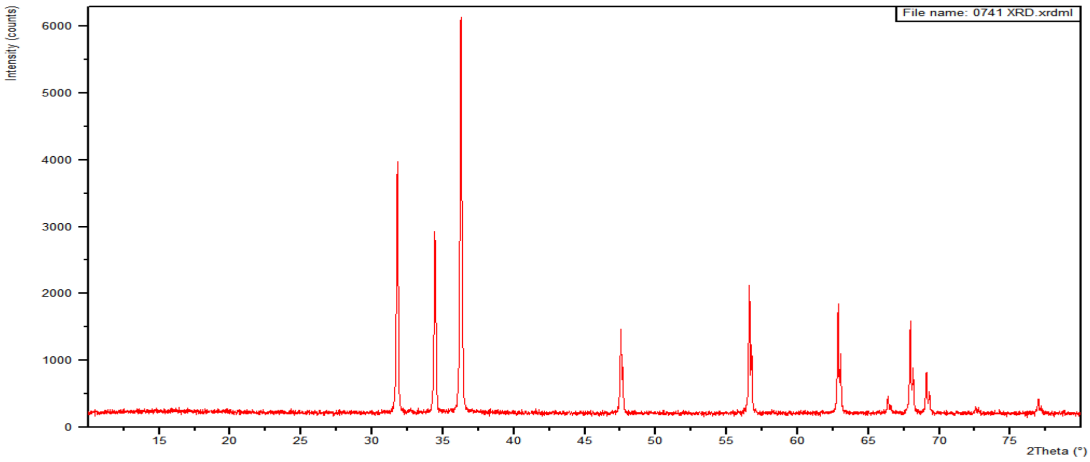

Figure 2. X-Ray Diffractogram of ZnO determined by XRD

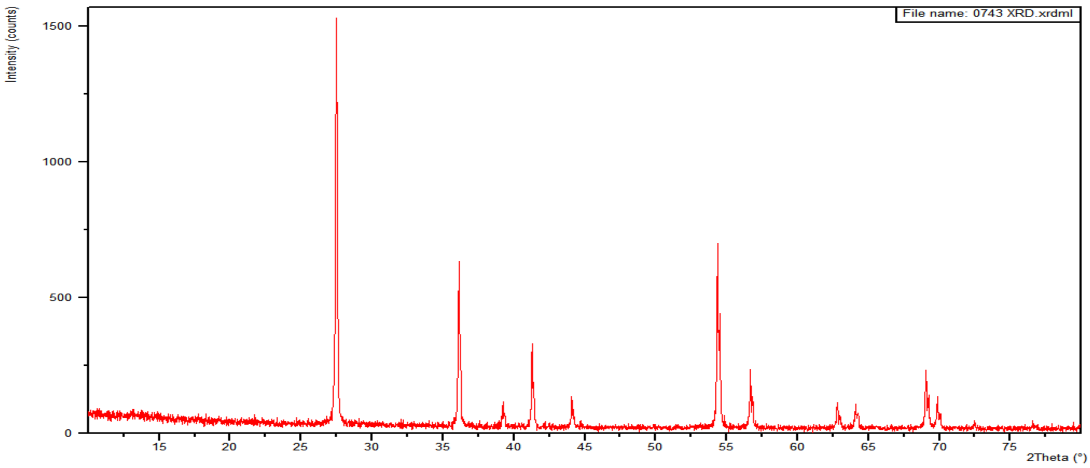

Figure 3. X-Ray Diffractogram of TiO2 determined by XRD

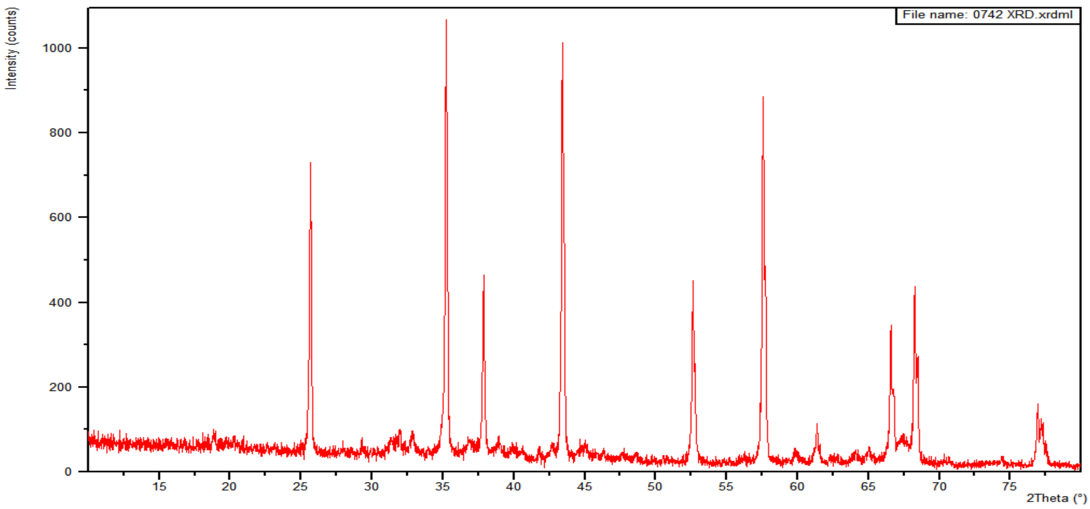

Figure 4. X-Ray Diffractogram of Al2O3 determined by XRD

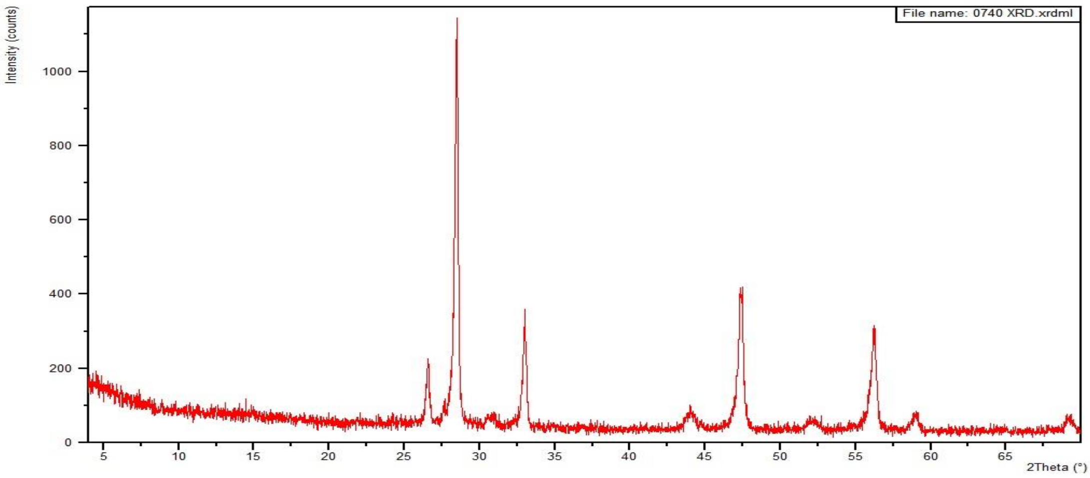

Figure 5. X-Ray Diffractogram of CeO2 determined by XRD

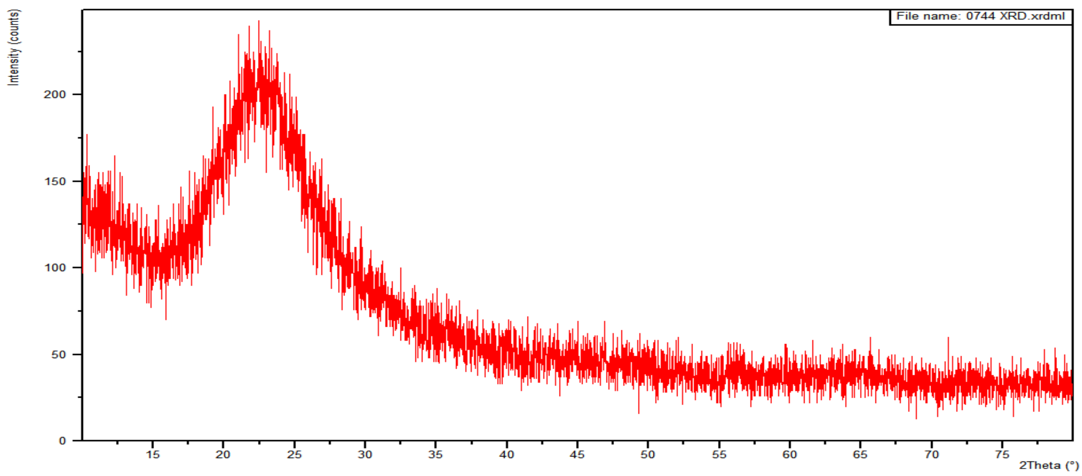

Figure 6. X-Ray Diffractogram of SiO2 determined by XRD

3.2. Experiment of Principle Sunscreen

Figure 7 shows an image of the experimental results of using sunscreen material on light-sensitive paper. Sunscreen material can reflect UV rays to keep the yellow color on light-sensitive paper from turning brown after exposure to sunlight.

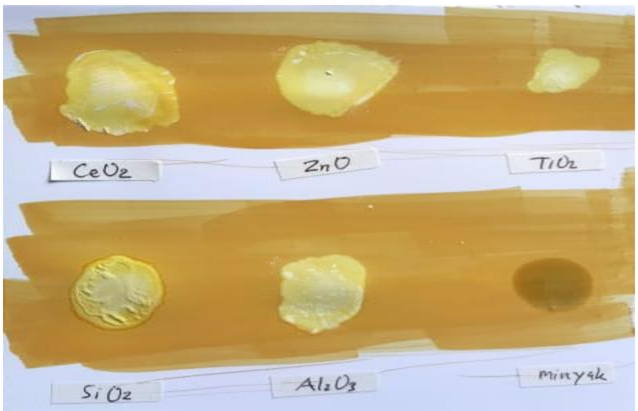

Figure 7. Experimental Result

Sunlight hitting the test layer will change the yellow color of the light-sensitive layer to brown. This phenomenon is because the light-sensitive liquid contains an active ingredient sensitive to ultraviolet light. The sunscreen material is used to protect the light-sensitive layer well so that it does not change even when exposed to sunlight, while the oil cannot cover the original color of the light-sensitive layer. This sunscreen ingredient is a physically active ingredient that reflects ultraviolet light. Physical sunscreen using in this study is ZnO [6], TiO_2 [4], SiO_2 [7], Al_2O_3 [8], and CeO_2 [9]. In physical sunscreens the active ingredient is an inorganic compound that works by physically reflecting or scattering the UV radiation [4]. Figure 8 illustrates the mechanics of a physical sunscreen.

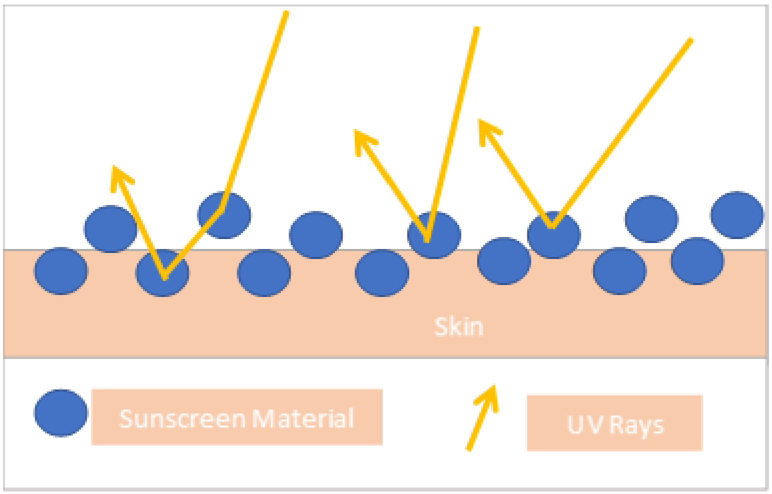

Figure 8. Sunscreen Agents – Mechanism of Action

3.3. Qualitative Analysis of Student

Table 2 shows the results of the Intelligence Quotient (IQ) test with an online test instrument (accessible via: www.tes-iq.com/tes-iq-anak). This test is for children from 6 to 10 years old. The test questions contain 30 questions and consist of three types of questions, namely looking for images that are different from the other four images, counting the number of boxes, and solving math problems or number patterns types. This IQ test aims to determine students' cognitive level because IQ can predict the level of intelligence of students, especially useful in understanding the concept of the material to be taught. Students with high IQ will more easily grasp the subject matter than students with low IQ [30]. The results of the IQ test showed seven students with test scores <95 in the intelligent category, eleven students with test scores <85 in the high category, and five students with test scores <75 in the normal class. Therefore, the average student has an IQ in the high category.

Table 2. Student IQ Score

Category of Score IQ Test	Total
Intelligent (<95)	7 Students
High (<85)	11 Students
Normal (<75)	5 Students

Table 3 shows students' demographics of the average score of mathematics, science, and Bahasa Indonesia. There is no significant difference between subjects' scores. The data also informs that the students have sufficient skills in science subjects. Therefore, the student's mastery in each subject is primarily similar.

Table 3. Student Report Score

Subject	Average Score
Math	72.61
Science	71.78
Bahasa Indonesia	72.17

3.4. The Pretest-Pottest Result of Student

Table 4 shows score for each question pretest and posttest. The question is the content of principle in sunscreen. The UV can reflect or absorb with material sunscreen and then introduce the sunscreen with video demonstration.

Table 4. Analyze Pretest-posttest Score

No	Question	% (Percentage) Pretest	Posttest	N-Gain
Section 1: Knowledge of UV rays				
1	Is UV light part of sunlight?	39.13	100	1
2	Can UV rays be reflected?	17.39	100	1
3	Can UV light be absorbed?	34.78	91.3	0.86
4	Can the eye see UV light?	26.08	95.65	0.94
5	Are UV rays harmful to human skin?	30.43	100	1
6	Is it essential to protect our skin from UV rays?	26.08	91.3	0.88
Section 2: knowledge about sunscreen				
7	Do you know and have ever heard of the term “sunscreen”?	30.43	91.3	0.87
8	Can sunscreen be used to protect the skin from UV rays?	34.78	91.3	0.86
9	Does sunscreen protect the skin by absorbing UV rays?	17.39	78.26	0.74
10	Does sunscreen protect the skin by reflecting UV rays?	30.43	91.3	0.87
11	Does sunscreen protect skin by absorbing and reflecting UV rays?	30.43	82.6	0.75
Section 3: Knowledge about ingredients Sunscreen				
12	Do you know the ingredients in sunscreen?	21.74	95.65	0.94
13	Is oil an ingredient used as an active ingredient in sunscreen?	26.08	86.95	0.82
14	Can oil be used to absorb and reflect UV rays?	34.78	91.3	0.86
Section 4: Knowledge about Chemical Active ingredients in Sunscreen				
15	Are ZnO and/or TiO2 chemicals used as active ingredients in sunscreens?	17.39	95.65	0.95
16	Do sunscreen ingredients containing ZnO and/or TiO2 function to absorb and reflect UV rays?	34.78	86.95	0.8
17	Can other chemicals be used as active ingredients in sunscreens besides ZnO and TiO2?	26.08	95.65	0.94
18	Can CeO2 be used as an active ingredient in sunscreen?	26.08	86.95	0.82
19	Can SiO2 be used as an active ingredient in sunscreen?	30.43	78.26	0.7
20	Can Al2O3 be used as an active ingredient in sunscreen?	8.69	78.26	0.76

Pretest score is assessing to know the abilities student about principal material, percentage 8.69%-39.13% show most of the student not familiar with this content. Posttest scores show improvement after the video is given, with a percentage of 78.26%-100%. Pretest and posttest can improve the understanding and growth of students' cognition [31].

Section 1 pretest-posttest results on questions number 1,2,3,4,5, and 6, which are questions about students' knowledge of UV rays. This problem provides knowledge that UV rays are part of sunlight (1) and can be reflected and absorbed (2 and 3), UV rays cannot be seen by the eye (4) and are harmful to the skin (5), so it is important to protect the skin from sunshine (6). The pretest results showed that there were still many students who were not familiar with UV rays after being given treatment, and the posttest results showed that students understood UV rays and the importance of protecting their skin from UV rays. The pretest and posttest results showed a significant difference with the N-gain value between 0.86-1 with high criteria so that students' understanding increased after being given a learning video. The UV light material being taught is new so that students' knowledge influences the success of students in understanding the material during science learning in class. In addition, IQ scores also affect student achievement because the picture of students who have sound intelligence reflects students who are good at their studies [32].

Section 2 pretest-posttest results on questions number 7, 8, 9, 10, and 11, which are questions of knowledge about sunscreen. The questions are designed so that students know (1) and understand that who can use sunscreen to protect the skin from UV exposure (8), sunscreen protects the skin by reflecting and absorbing UV rays (9,10, and 11). The pretest results showed that students' knowledge about sunscreen was still low with a percentage of 17.39-34.78%. after being given a learning video, students' understanding increased by a percentage of 78.26-91.3%. The pretest and post-test results have a high significance with an N-gain value of 0.74-0.87 with a highly significant criterion, meaning that students' understanding increases after being given a sense of concepts through video. This result is also supported by the value of science and students' high IQ scores because of a relationship between IQ scores and student achievement [33].

The results of section 3 pretest-posttest on questions number 12, 13, and 14 related to knowledge of the content in sunscreen (12) and learning that oil (a distractor) is not an active ingredient in sunscreen (13), besides that oil cannot absorb or reflect UV light (14). The pretest results showed that, on average, students did not know the ingredients in sunscreen and were still fooled that oil is the active ingredient of sunscreen. Students' understanding changed after being given an experimental demonstration in the video. On average, students knew that oil was not a sunscreen ingredient and could not absorb or reflect UV rays. These results can be seen in the high percentage of posttest scores. The significance between the pretest and posttest values is also high, seen from the N-gain values are 0.94, 0.82, and 0.86.

The result of section 4 pretest-posttest results on questions number 15 to 20, which are questions of knowledge about the various active ingredients in sunscreen. The questions in this section provide knowledge that apart from ZnO and TiO_2, which are often used as active ingredients in sunscreens, other alternative materials used are CeO_2, SiO_2, and Al_2O_3. Sunscreens that protect the skin by reflecting and absorbing UV rays contain chemical and physical ingredients such as the materials used in this experiment, namely ZnO, TiO_2, SiO_2, Al_2O_3, and CeO_2. The pretest results showed that students were not familiar with the active ingredients used in sunscreen. The students' pretest scores in this section were low among other questions, which were between 8.69 to 34.78. The material regarding the understanding of

chemicals in elementary schools is still new. Students have never studied it, but after being given a video, students' understanding increases based on the posttest results with a percentage of 78.26-95.65%.

Students can quickly understand this difficult-to-understand material, and it can be related to the average student's IQ score in the high category. The pretest and posttest values based on N-gain have a medium significance on question number 19, namely 0.7, while the high significance on questions number 15, 16, 17, 18, and 20 are 0.95, 0.8, 0.94, 0.82, and 0.76, respectively. Analyze wheter there is a significat difference between the pretest and posttest scores. The increase in student learning outcomes is analyzed for each question with a normalized gain score. The result show that N gain > 0.7 in criteria high significant [28]. Therefore the learning video significantly increase the students' mastery in understanding the principle of sunscreen using various material. The success of teaching supported by this video is in line with our previous research, namely: Video learning in islamic religious education [34], Application of learning videos and quizizz [35], Digital literacy on poster learning in elementary schools [36], Japanese students in using online video as a learning media [37], learning videos to increase student motivation [38], animated videos for Junior High School Students [39], professionals' verdict on video instructional package for junior secondary school [40].

Conclusion

Teaching the principle of sunscreen materials using ZnO, TiO_2, SiO_2, Al_2O_3, and CeO_2 has been studied. Sunscreen materials can reflect and absorb UV rays except for oil in this experiment. The result of the pretest-posttest shows that the learning video improves students' understanding of the principle of sunscreen using various materials. Future research can teach another interesting applied chemistry topic to improve students' understanding of elementary school students.

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