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Zinc Oxide Nanoparticles for Enhancing Students' View of the Nature of Science and Technology

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ABSTRACT

This study aims to evaluate zinc oxide (ZnO) nanoparticles as a learning media to enhance students' understanding of View of Nature of Science and Technology (VNOST). The method used in this study: (i) understanding how to synthesize ZnO nanoparticles using a liquid-phase synthesis; (ii) implementating of ZnO nanoparticles synthesis in the teaching and learning process, and students and analyzing their comprehension using Transcript Based Lesson Analysis (TBLA) on the Learning Video Recording and Adaptation Learning Transcript VNOST questionnaire, which is linked to the implementation and pattern of knowledge construction; and (iii) analyzing the understanding of VNOST for each Category (Naïve, Has, Merit, and Realist). To support this study, several analyses were done, such as a scanning electron microscope and X-ray diffraction to characterize ZnO nanoparticles' morphology and crystal structure, respectively, prior to giving this material for further learning to students. Experimental results showed that the use of ZnO nanoparticles is effective to improve the student comprehension. The understanding in the principle of nucleation and growth can be explained well since the reaction of ZnO is relatively fast. Students became more serious in listening during the learning process and more curious to study science and technology. Based on a comparative analysis of the initial and final ability of VNOST, it is proved that there was a change in students' views related to science and technology.

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1. INTRODUCTION

Efforts to connect science and technology for teaching-learning process can be done through techno-science education. Techno-science connects abstract concepts to be more tangible in the material-cognitive design medium, which provides students with a concrete view on modelling as a means to produce scientific knowledge (Wang, 2004). In the context of chemistry, techno-science is called techno-chemistry. Techno-chemistry refers to activities originating from chemical experiments, which are fundamentally and based on a certain set of values, transforming the reality of life (Fan & Lu, 2005).

One of the prospective models for techno-science learning is teaching techno-chemistry using zinc oxide (ZnO) nanoparticles. Reports on the synthesis of ZnO nanoparticles have been well documented. All results showed that ZnO nanoparticles were easily produced and the reaction is very fast (Aneesh *et al*., 2007). However, reports on the use of ZnO nanoparticles as a teaching media is rarely reported.

Based on our previous studies in the teaching and learning science and technology to student (Haristiani *et al*., 2007; Nandiyanto *et al*., 2018). Here, we reported the effectiveness of ZnO nanoparticles as a learning media for supporting teaching senior high school students. Teaching ZnO nanoparticles was implemented in the learning process using a View of Nature of Science and Technology (VNOST). As mentioned above, the main reason for the use of ZnO nanoparticles is because this type of material can be prepared easily and rapidly from zinc raw materials. This material can be also found in daily life in various products such (Naito *et al*., 2018; Wilke & Waitz, 2014).

2. METHOD

2.1. Synthesis of ZnO Nanoparticles

ZnO nanoparticles were synthesized using a liquid-phase synthesis. In short, the material was produced by reacting zinc acetate (Zn(CH3COO)2. 2H2O; Sigma Aldrich, US) and sodium hydroxide (NaOH; Bratachem, Indonesia) in ethanol solution (99%; Sakura, Indonesia). In short, the synthesis procedure was done into three steps: (i) diluting reactants, (ii) reaction process, and (iii) purification.

The first step was done by dissolving zinc acetate and NaOH separately into ethanol. Zinc acetate was dissolved at temperature of 60°C for 2 hours, whereas NaOH dissolution was done at 40°C for 2 hours.

In the second step, both reactants (i.e. zinc acetate and NaOH solutions) were put into borosilicate reactor and mixed for 2 hours. In this study, we varied the concentrations of zinc acetate (from 0.10 to 0.50 M) and NaOH (from 0.07 to 0.35 M).

In the final step, the mixed solution was then put into a centrifugation process (11,000 rpm; 5 minutes). The centrifuged samples were then dried at 100°C in electrical furnace to remove solvent.

To confirm that ZnO nanoparticles were successfully produced, the samples were characterized using a scanning electron microscope (SEM; SU-3500, Hitachi, Japan; for analyzing particles' size and morphology) and a powder X-ray diffraction (XRD; Smartlab 3kW, Rigaku, Japan; for analyzing the crystal structure formed in the sample).

2.2. Teaching ZnO Nanoparticles to Students

The study was conducted on 20 senior high school students in Bandung with ages of 16 -17 years old. To teach the concept on the implementation of ZnO nanoparticles, we conducted into several steps:

(i) Demonstrating synthesis of ZnO nanoparticles
(ii) Implementing ZnO nanoparticles in teaching and learning process in 2 x 45 minutes.
(iii) Recording learning process with the aim at seeing the dialogue during the learning process. Learning video was encrypted as a transcript using Transcript Based Lesson Analysis (TBLA).
(iv) Analyzing results using the TBLA analysis in four segments according to the four aspects of VNOST for examining VNOST construction in students' perspective.
(v) Focusing analysis of learning transcripts on student dialogue in learning. This response is compared as a communicative function for representing the construction of student knowledge (See **Table 1**) (Abdullah *et al*., 2009; Guedens *et al*., 2013; Tairab, 2001).

2.3. Implementation of VNOST

To analyze students' comprehension, we used VNOST questionnaire. VNOST questionnaire was grouped into four categories:

(i) View of science, the purpose of science, and the nature of scientific research;

(ii) View of technology;

(iii) A view of scientific knowledge, scientific theories, and scientific discoveries;

(iv) A view of the relationship between science-technology-society.

To discuss students' perspectives on VNOST, each question was classified according to three categories (Tala, 2009; Chamizo, 2013):

(i) Realistic / R: expression as an appropriate view.

(ii) Has Merit / HM: expression as a legitimate factor.

(iii) Naïve / N: expression as an improper or invalid factor.

Table 1. Response type classification

Response Type	Coding	Description
Interrogative	Q	Asking for pieces of opinion, information, advice or clarification
Responsive	A	Answering questions or providing clarification
Suggestive	S	Giving advice relating to the topic of discussion
Informative	I	Providing information related to the topic of discussion. Information in the form of theoretical knowledge
Exemplification	EX	Giving a concrete / real example
Elaborative	EL	Developing further pieces of information, suggestions or examples offered previously
Justificational	JT	Justifying pieces of information, suggestions or examples
Reasoning	RE	Giving reasons about knowledge
Evaluating	EV	Providing positive feedback on pieces of information, suggestions, and examples offered previously
Judgmental	J	Expressing agreement to pieces of information, suggestions or examples offered
Summarizing	S	Summarizing pieces of information, suggestions or examples given previously

3. RESULTS AND DISCUSSION

3.1. Synthesis and Characterization of ZnO Nanoparticles

Figure 1 shows the SEM analysis images of ZnO nanoparticles prepared with various concentrations of reactants. The results showed that various particles' morphologies were obtained.

When using concentration ratio of zinc acetate and NaOH of 0.05/0.35 (See **Figure 1(a)**), the particles had spherical shapes with mean sizes of 533 nm. Some particles were agglomerated. Broad sizes of particles were obtained, which were in the range of 80 to 3,000 nm. When the concentration ratio was 0.10/0.07 (See **Figure 1(b)**), the spherical particle sizes were about 399 nm. When the concentration ratio was 0.20/0.14 (See **Figure 1(c)**), flakes with mean sizes of about 400 nm were obtained. When using a concentration ratio of 0.50/0.35 (See **Figure 1(d)**), the larger flakes were obtained, in which the mean sizes were about 500 nm. Flakes were transformed into flower-like flakes.

Figure 2 shows the XRD analysis results of samples prepared with various concentrations of reactants. The XRD showed the qualitative and quantitative data from the ZnO nanoparticles. The crystal structure and crystallinity of ZnO nanoparticles were identified, in which this has been confirmed by the Join Powder Diffraction System (JCPDS) no 05-0664 (Kanade *et al*., 2006). The results showed that the sequential standard peaks at 31.75; 34.44; 36.25; 47.54; 56.55; 62.86; 66.38; 67.91; 69.05; 72,60; and 76.95° were identified, which were identical to ZnO structure. The change in the reactant composition was found in the XRD intensity only, but the crystal structures (XRD patterns) are still for ZnO material.

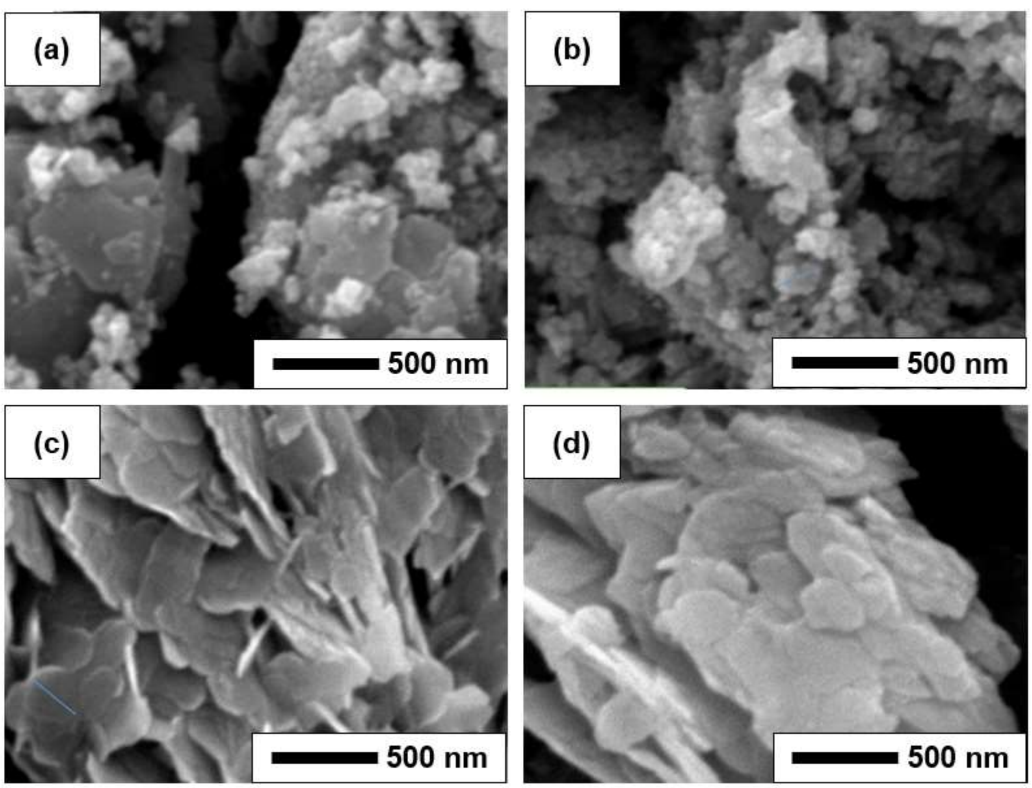

Figure 1. SEM images of ZnO nanoparticles prepared with various concentration ratios of $Zn(CH_3COO)_2$ and NaOH: (a) 0.05/0.35; (b) 0.10/0.07; (c) 0.20/0.14; (d) 0.50/0.35

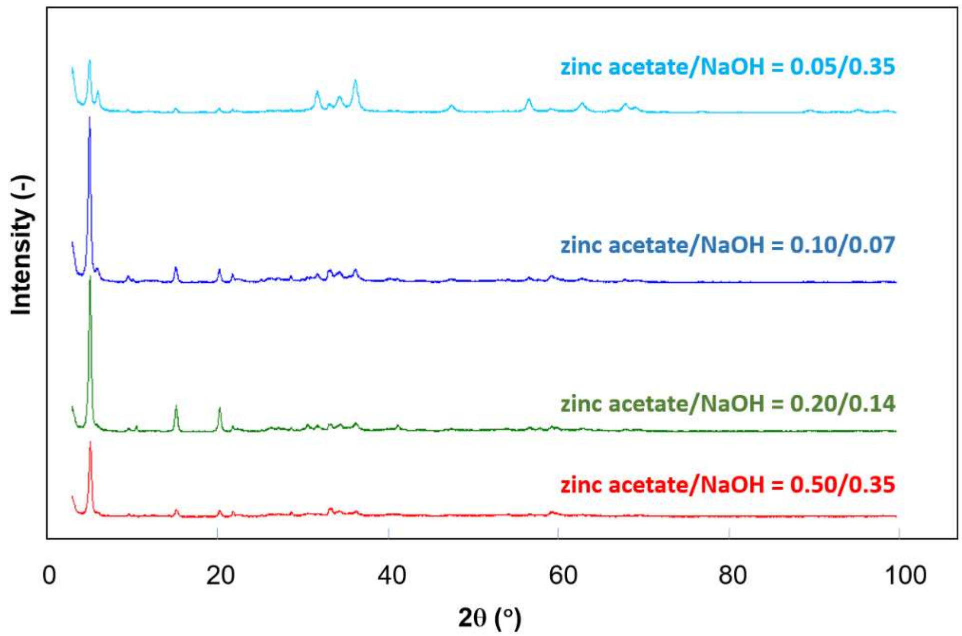

Figure 2. X-Ray diffraction patterns of ZnO nanoparticles prepared with various concentration ratios of zinc acetate and NaOH

3.2. Analysis of Learning ZnO Nanoparticles

Figure 3 shows the construction patterns based on VNOST analysis. In this figure, we divided figures based on 4 segments. In each segment, we used 11 types of responses. In all segments, there are only 5 or 6 types of responses. Most of the types of responses were 2, 4, 6, 8, 10, and 11, corresponding to responsive, informative, elaborative, reasoning, judgmental, and summarizing, respectively.

Figure 3(a) provides information about five types of responses appeared in segment-1. The five responses (*i.e.,* 2, 4, 6, 8, and 10) showed that the dialogue between our study and students relating to aspects of the definition of science and technology (more directed towards responsiveness). We found that the answers from students still used the term of repetition from teachers. Indeed, this gives information that the students have not yet understood correctly.

Figure 3(b) provides information relating to the types of responses that arise in aspects of the epistemology of science. There are five types of responses: 2, 4, 6, 8, and 10. Based on the types of responses, it can be interpreted that dialogues between students and teachers are more dominant in the judgmental type. Judgmental type provides an illustration that students can express only approval for pieces of information, suggestions, or examples (Tala, 2009).

Figure 3(c) provides information relating to aspects of internal sociology of science. We found four types of responses (*i.e.,* 2, 4, 6, and 10). In this segment, informative response types were more dominant in learning on the topic of ZnO nanoparticles. Informative type illustrates that students provided information in the form of knowledge relating to the topic under discussion (Tala, 2009).

Figure 3(d) shows information about the type of response arising in segment 4. There are six responses appearing: 2, 4, 6, 8, 10, and 11. We found that students can summarize pieces of information, suggestions, or examples explained previously (Tala, 2009). This also shows the information given by the teachers to students are not done directly, but teacher's guide and help students to achieve information and build critical perspective (Rajendra *et al*., 2010; Saravanan *et al*., 2012; Rubba & Harkness, 1996).

3.3. VNOST Student Understanding

Table 2 illustrates that students' general understanding of VNOST. We used four aspects, in which each aspect has several sub aspects. We found that there is a change in the VNOST percentage. The sub-aspect of the definition of science as a whole information has changed in a more desirable direction, namely the change from *Naive* to *Has merit*, and from *Has merit* to *Realist*.

The sub-aspect of the definition of science as a whole has changed in a more desirable direction, namely the change from *Naive* to *Has merit*, and from *Has merit* to *Realist*. The reasons for choosing answers for choosing *Realist* statements on the definition of science are from the way how students discussed and selected. One of the answers from students is that "*science is a process of inquiry because every development of an age of researchers always finds something new, it continues, and it develops*". This view is appropriate because science can be defined as the process of building scientific knowledge (Laherto, 2012; Yahya, 2013; Velmurugan *et al.*, 2010). Therefore, it can be concluded that learning activities in the sub-aspects of the definition of science can be applied to strengthen students' VNOST.

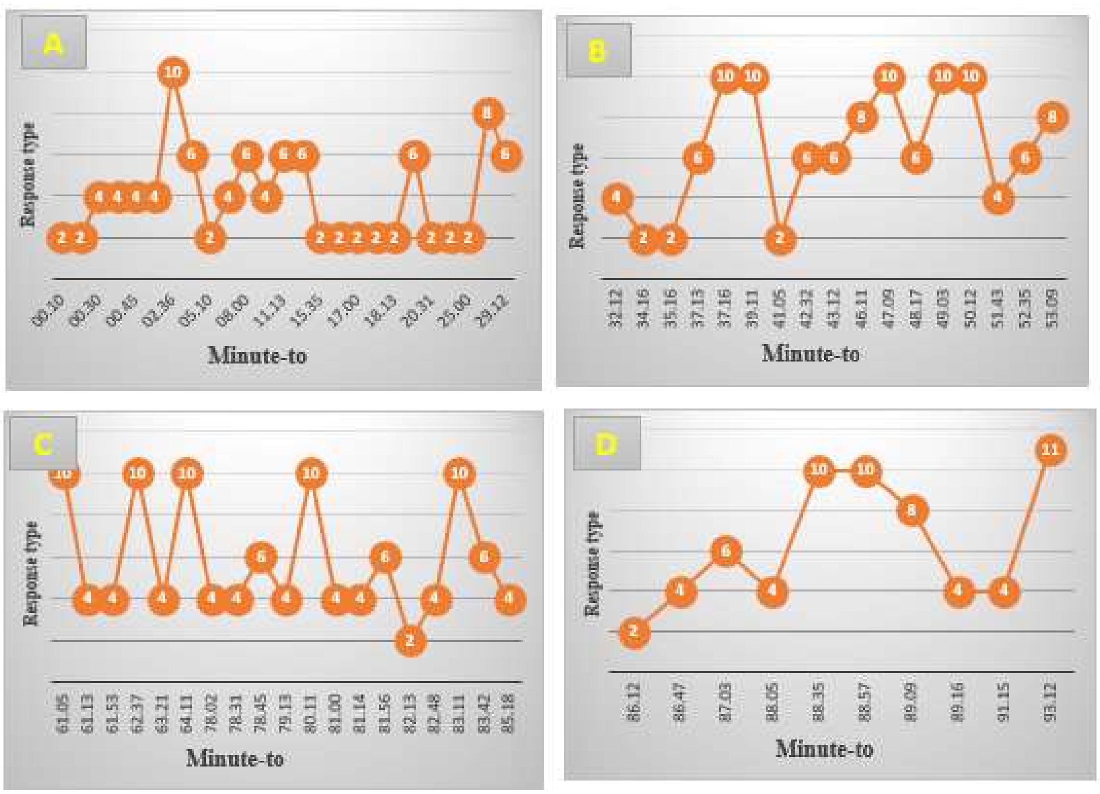

Figure 3. Student construction patterns: (a) Segmen-1 (0-29s); (b) Segmen-2 (32-53s); (c) Segmen-3 (61-85s); (d) Segmen-4 (85-93s)

Table 2. Frequency and percentage of student VNOST comparison before and after learning

No	Aspect NOST	Sub Aspect NOST	Category	%Initial	%Final	Change (%)
1	Definition Science and Technology	Definition of science	*Realist*	15	15	0
			Has merit	80	85	5
			Naïve	5	0	-5
		Definition of Technology	*Realist*	5	15	10
			Has merit	95	85	-10
			Naïve	0	0	0
		The relationship between science and technology	*Realist*	35	65	30
			Has merit	50	30	-20
			Naïve	15	5	-10
2	Epistemology of Science	The nature of the scientific model	*Realist*	25	40	15
			Has merit	15	40	25
			Naïve	60	20	-40
		The nature of the classification scheme	*Realist*	30	50	20
			Has merit	10	15	5
			Naïve	60	35	-25
3	Internal Sociology of Science	The nature of scientific decisions	*Realist*	40	60	20
			Has merit	40	40	0
			Naïve	20	0	-20
		The nature of technology decisions	*Realist*	45	30	-15
			Has merit	50	70	20
			Naïve	5	0	-5
4	External Sociology of Science	The relationship between science and technology and society	*Realist*	15	30	15
			Has merit	35	45	10
			Naïve	50	25	-25

Note: Change% = final% - initial%

The second sub-aspect of technology definition has changed the view from Merit to Realist. But, in the sub-aspect of technology definition, some students still have difficulty understanding the technological definition. This is verified from the fact that many students still selected the statement of Merit namely "the application of science that is useful to improve the quality of life". One of the reasons is from the statement of students that is "because technology is one of the developments in science that comes from several components. Science can be used as a tool to improve the quality of life. Examples can be found in daily life such as handphone and computers". Students tend to vaguely interpret technology as a field relating to improving quality of life. Students found a limit about the scope of technology for the achievement of modern technology (Arvaja, 2007).

For the third sub-aspect, the relationship between science and technology changed. We found that students can be classified namely the change from Naive to Has merit, and from Has merit to Realist. Referring to the old view of science and technology, they are two different views and separated each other. But, they interconnected each other (Tairab, 2001). In the sub-aspects of the relationship between science and technology, 13 students already have a Realistic view. This means that the developed didactic design is valid to strengthen VNOST students, especially linking science and technology to the learning of nano-scaled ZnO particles. Students argue that "the development of science enables people to create technology and practical applications. The development of technology today makes it easier for humans to explore science". This explains that the relationship between science and technology is related to how scientific knowledge is arranged and used to explain phenomena in a technology and how the technology affects society and vice versa (Tala & Vesterinen, 2015; Lederman et al., 2013).

In the fourth sub-aspect, the nature of the scientific model changed the views of students towards the more desirable: i.e., to have a Realist view. As many as 8 students underwent a change that initially had the view of Naive to become Merit and Realist. This gave an illustration that the didactic design situation is able to facilitate students to have the view that the scientific model, in which this is different from the original object. Students argue "because although scientists say that the model is true to the original form; in my opinion, the model is only a picture of the original object only".

In the fifth sub-aspect, the nature of the classification scheme showed that as many as 10 students were in the view of Realistic view. Students were able to define the nature of the classification scheme. This is confirmed from the fact that many students selected a Realist statement which is "there are many ways to classify something, but it needs to be agreed upon a universal system. So, it will not cause confusion". One of the reasons from students is the statement that "because science will change over time, but we need to agree on a system. Thus, it will not get confusing while studying it".

In the sixth sub-aspect, the nature of scientific decisions changed from Naive to Has merit, and from Has merit to Realist. Students are able to define that scientific decisions have been successfully tested many times and no one has denied them. The didactical design situation and our anticipation were in line with our expectations. This is strengthened by the student's statement that "because it is tested many times, it proves that the theory is correct and it will thus strengthen our scientific theory and it cannot be refuted".

In the seventh sub-aspect, technology decisions showed that many students still have Has merit views. But, there is a change from Naive to Has merit. This shows that students experience difficulties relating to technology decisions. Students argued that "when a technology is present, not only the impact that needs to be considered. It also correlates to how to work, price, and efficiency. It also needs to be considered. Thus, it should be easily accessible to all people, making working easily" (Al-Najar & El Hamarneh, 2019).

In the eight sub-aspect, the relationship of science, technology, and society has changed the outlook from Naive to Merit and some students have Realist. The main reason for the fact that some students have a Realistic view is because of their statement that "the progress of a nation depends on the development of science and science technology". Didactical design situation that was designed in accordance with what is obtained (Hudson, 2008). Students argued that "the quality of a nation depends on the development of science and technology. The more advanced science and technology, the better the quality of a nation can be obtained. This relates to its facilitation".

From the results of the frequency and percentage of students' VNOST comparisons and some of the reasons underlying the VNOST knowledge construct owned by students, it can be concluded that learning science and technology from the support of the use of ZnO nanoparticles has the potential to strengthen students' VNOST.

4. CONCLUSION

This study has evaluated the use of ZnO nanoparticles as a learning media to enhance students' understanding of VNOST. We found that the use of ZnO nanoparticles is effective to improve the student comprehension. Students become more serious in listening during the learning process. They also have been more curious to study science and technology. Based on a comparative analysis of the initial and final ability of VNOST, it is proved that there was a change in students' views related to science and technology.

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6. REFERENCES

Abdullah, M., Virgus, Y., Nirmin, N., & Khairurrijal, K. (2009). Sintesis Nanomaterial. *Jurnal Nanosains & Nanoteknologi*, *1*(2), 33-57.

Al-Najar, H., & El Hamarneh, B. (2019). The Effect of Education Level on Accepting the Reuse of Treated Effluent in Irrigation. *Indonesian Journal of Science and Technology*, *4*(1), 28-38.

Aneesh, P. M., Vanoja, K. M., & Jayaraj, K. (2007) Synthesis of ZnO nanoparticles by hydrothermal method. *Nanophotonic Mater*, 4(6639), 1–9.

Arvaja, M. (2007). Contextual perspective in analysing collaborative knowledge construction of two small groups in web-based discussion. *International Journal of Computer-Supported Collaborative Learning*, *2*(2-3), 133-158.

Chamizo, J. A. (2013). Technochemistry: One of the chemists' ways of knowing. *Foundations of Chemistry*, *15*(2), 157-170.

Fan, Z., & Lu, J. G. (2005). Zinc oxide nanostructures: synthesis and properties. *Journal of nanoscience and nanotechnology*, *5*(10), 1561-1573.

Guedens, W. J., Reynders, M., Van den Rul, H., Elen, K., Hardy, A., & Van Bael, M. K. (2013). ZnO-based sunscreen: The perfect example to introduce nanoparticles in an undergraduate or high school chemistry lab. *Journal of Chemical Education*, *91*(2), 259-263.

Haristiani, N., Aryanti, T., Nandiyanto, A. B. D., & Sofiani, D. (2017). Myths, Islamic View, and Science Concepts: The Constructed Education and Knowledge of Solar Eclipse in Indonesia. *Journal of Turkish Science Education (TUSED)*, *14*(4).

Hudson, B. (2008). A didactical design perspective on teacher presence in an international online learning community. *Tidskrift för lärarutbildning och forskning: Journal of Research in Teacher Education*, 15(3-4), 93-112.

Kanade, K. G., Kale, B. B., Aiyer, R. C., & Das, B. K. (2006). Effect of solvents on the synthesis of nano-size zinc oxide and its properties. *Materials Research Bulletin*, *41*(3), 590-600.

Laherto, A. (2012*). Nanoscience education for scientific literacy: Opportunities and challenges in secondary school and in out-of-school settings.* Dissertation. Helsinki: University of Helsinki.

Lederman, N. G., Lederman, J. S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics Science and Technology*, *1*(3), 138-147.

Naito, M., Yokoyama, T., Hosokawa, K., & Nogi, K. (Eds.). (2018). *Nanoparticle technology handbook*. Elsevier.

Nandiyanto, A. B. D., Asyahidda, F. N., Danuwijaya, A. A., Abdullah, A. G., Amelia, N., Hudha, M. N., & Aziz, M. (2018). Teaching "Nanotechnology" for elementary students with deaf and hard of hearing. *Journal of Engineering Science and Technology (JESTEC)*, *13*(5), 1352-1363.

Rajendra, R., Balakumar, C., Ahammed, H. M., Jayakumar, S., Vaideki, K., & Rajesh, E. (2010). Use of zinc oxide nano particles for production of antimicrobial textiles. *International Journal of Engineering, Science and Technology*, *2*(1), 202-208.

Rubba, P. A., & Harkness, W. J. (1996). A new scoring procedure for the Views on Science-Technology-Society instrument. *International Journal of Science Education*, *18*(4), 387-400.

Saravanan, M., Dhivakar, S., & Jayanthi, S. S. (2012). An eco friendly and solvent free method for the synthesis of Zinc oxide nano particles using glycerol as organic dispersant. *Materials Letters*, *67*(1), 128-130.

Tairab, H. H. (2001). How do pre-service and in-service science teachers view the nature of science and technology?. *Research in Science & Technological Education*, *19*(2), 235-250.

Tala, S. (2009). Unified view of science and technology for education: Technoscience and technoscience education. *Science & Education*, *18*(3-4), 275-298.

Tala, S., & Vesterinen, V. M. (2015). Nature of science contextualized: Studying nature of science with scientists. *Science & Education*, *24*(4), 435-457.

Velmurugan, K., Venkatachalapathy, V. S. K., & Sendhilnathan, S. (2010). Synthesis of nickel zinc iron nanoparticles by coprecipitation technique. *Materials Research*, *13*(3), 299-303.

Wang, Z. L. (2004). Zinc oxide nanostructures: growth, properties and applications. *Journal of physics: condensed matter*, *16*(25), R829.

Wilke, T., & Waitz, T. (2014). 'NANO'–An Attractive Dimension for School Chemistry Education. In *Conference proceedings. New perspectives in science education*, 82.

Yahya, N. (2013). *Carbon and oxide nanostructures*. Springer-Verlag Berlin An.