Improved learning designs for shaping Indonesia's future science teachers applied in a nanoscience project

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This study aimed to develop pre-service science teachers' conceptual understanding of a nanoscience project through a newly introduced 8E learning cycle. This research was conducted during one semester of a nanoscience and nanotechnology course in the chemistry education department in Universitas Negeri Jakarta, Indonesia with thirty-three pre-service chemistry teachers. Data collection was carried out using classroom observation, in-depth interviews, reflective journals, and a chemistry test that explored pre-service teachers' conceptual understanding of nanoscience and nanotechnology. The 8E learning cycle consists of Engage, Explore, E-Search, Elaborate, Exchange, Extend, Evaluate, and Explain. The results show that the learning cycle engaged pre-service teachers in developing their conceptual understanding through collaboration, discussion, and reflection. The pre-service teachers understood the concepts of unique characteristics, physical properties, and chemical properties of nanomaterials. In each step of the 8E learning cycle, pre-service teachers reflected on and constructed their understanding within the principles of individual and social learning. The results showed that the 8E learning cycle can be used to develop pre-service teachers' conceptual understanding of nanoscience and nanotechnology and social skills.

Introduction

Teachers play an important role in engaging students in current issues, especially in relating to numerous rapid advances in science and technology. Therefore, teacher education programs need to create a transformative curriculum that can engage pre-service teachers in reflecting on their competencies that include engaging in different ways of knowing, and learning about current issues in science and technology. In science learning, conceptual and procedural knowledge of science play an important role in innovation and technological development (Lee & Kwok, 2017; McCormick, 1997). Therefore, pre-service teachers' conceptual understanding is important for the development of science and technology. Even though the relationship between science and the development of new technology may be poorly understood (Lawrence & Bryan, 2002), teachers are required to engage students' thinking and develop their competencies in the face of these developments.

Nanoscience and nanotechnology are current issues in technology development that involve multidisciplinary fields of science. According to Ghattas and Carver (2012) and Tretter (2006), advances in abilities to synthesise materials at a nanoscale provide opportunities for nanotechnology development (Ghattas & Carver, 2012; Tretter, 2006). Technological developments in nanoscience have created increasing, unmet needs for expert workers in this field (Gilbert & Lin, 2013). However, nanoscience education is still in its infancy, and unlike other areas of science education, understanding and research on how to teach the core ideas of nanoscience and nanotechnology are still emerging

(Greenberg, 2009). As nanoscience and technology continue to grow, there is an increased need to educate a new generation of technicians, scientists, engineers, entrepreneurs, policy-makers, regulators and communicators who are knowledgeable in this emerging field (Jones et al., 2013; Yawson, 2010).

Students' competencies that are sought keep changing according to the times. Education today is a major challenge for the development of nanotechnology (Jones et al., 2013; Roco, 2003). Chemistry teacher education programs aim to prepare students with competencies that are in accordance with technological knowledge, chemical content, and pedagogy, including being able to explain applications of chemistry in other fields of science. One of these is nanoscience and nanotechnology, which if not addressed creates a risk of slowing some developments in scientific and technological advances (Jones et al., 2013). To overcome such challenges, student knowledge needs to be developed by competent teachers (Rahmawati, Koul & Fisher, 2014). One important teacher competency is conceptual understanding. In the Indonesian context, several problems are evident in relation to learning chemistry. Linking abstract concepts to students' daily lives is a problem that limits effective chemistry education. It is expected that students will understand chemistry concepts, and also be able to relate contemporary issues to chemistry and play an active role in solving problems, either in the form of ideas or actions (Rahmawati & Ridwan, 2017). To achieve these objectives, learning to teach chemistry must also develop students' abilities in social life; to resolve the kinds of problems that require both a good conceptual understanding and creativity in applying chemistry to contextual issues in everyday life, to enable more meaningful learning experiences. In this research context, one of the courses for pre-service chemistry teachers is nanoscience and nanotechnology.

The nanoscience and nanotechnology course provides an understanding of concepts and application issues of in this topic. The study of science must flow from basic concepts to functional benefits and then proceed to practical applications that can be used in real-world situations (Feather & Aznar, 2010). Therefore, in this course, pre-service chemistry teachers were expected to understand and explain the definition of nanoscience, nanomaterials, and nanotechnology, the unique characteristics of nanomaterials, and the physical and chemical properties of nanomaterials. One of the requirements for achieving this goal was a sound understanding of the concepts of nanoscience. Nanoscience and nanotechnology education also aims to improve understanding in conceptualising objects and processes from nano-sized material (Schönborn, Gunnar, & Palmerius, 2016), and the relating of chemistry concepts to technological development. The main challenge is to develop students' understanding of nanoscience and nanotechnology as an interdisciplinary science that can help improve their conceptual understanding (Jones et al., 2013).

The researchers conducted preliminary studies of pre-service chemistry teachers' understanding through an interview that questioned basic chemistry concepts. Participants stated that they were interested in the application of nanoscience, which is currently widely used, but chemistry test results showed that they had a low understanding of chemistry concepts related to nanoscience and nanotechnology. Deficiencies in their

conceptual understanding relates to an inability to associate the initial concepts they have to explain and understand about nanoscience (Hingant & Albe, 2010; Light et al., 2007; Roco, 2003; Schönborn, Höst, & Lundin Palmerius, 2015). Therefore, the problem of pre-service teachers' conceptual understanding in nanoscience and nanotechnology needs to be addressed. One way to achieve this is by using the *8E learning cycle* in the nanoscience and nanotechnology course.

The researchers applied the 8E learning cycle, developed from an existing learning cycle model by Ridwan and Rahmawati (2016). The 8E learning cycle comprises eight stages: engage, explore, e-search, elaborate, exchange, extend, evaluate, and explain. The model is based on constructivist learning theory where students build their understanding based on their initial knowledge (Blank, 2000; Musheno & Lawson, 1999; Qarareh, 2012). The learning cycle model continues to be developed from the several versions of learning cycles that appear in the literature, ranging from the 3E learning cycle developed by Robert Karbles in 1960 for science learning (Qarareh, 2012), the 5E learning cycle (Bybee, 1997; Bybee et al., 2006), and the 7E learning cycle (Eisenkraft, 2003) which uses the following stages: elicit, engage, explore, explain, elaborate, evaluate, and extend (Balta & Sarac, 2016; Duran, Duran, Haney & Scheuermann, 2011; Eisenkraft, 2003). All the learning cycles have a student-centred approach so students can carry out active learning. The learning cycle has changed because of the change in learning methods that students can use. The 8E learning cycle was implemented to develop students' cognitive structure, understanding, and to help overcome misconceptions (Darmiyanti, Rahmawati, Kurniadewi, & Ridwan, 2017; Mahardika, Ridwan, & Rahmawati, 2018; Ridwan & Rahmawati, 2016). The 8E learning cycle was developed based on the principles of personal and social constructivism. The lecturer acts as facilitator, helping pre-service teachers construct their knowledge. The 8E learning cycle emphasises the development of pre-service teachers' cognitive abilities through the exploration of their initial understanding, the use of ICT, discussion, and reflection on their understanding in order to gain understanding of new concepts. Therefore, the research aims to develop pre-service teachers' understanding through the 8E learning cycle.

Method

This research was conducted during the first semester of the 2018/2019 academic year. The study participants were 33 pre-service teachers who were third-year students in the chemistry education department, Universitas Negeri Jakart, including 5 male students and 18 female students with age range 20 to 22 years. The university is one of a number of state universities in Indonesia where students are prepared to become secondary school chemistry teachers. Nanoscience and Nanotechnology is an optional unit for chemistry pre-service teachers with 2 credits (50 minutes contact hours for each credit) delivered in second semester each year. The prerequisite for taking Nanoscience and Nanotechnology course is Material Chemistry. The 8E learning cycle was conducted over eight meetings in the Nanoscience and Nanotechnology unit course (100 minutes contact time for each meeting). The research was conducted to explore the descriptions, views, and explanations about the pre-service teachers' conceptual understanding of nanoscience and

nanotechnology through the 8E learning cycle. Learning activities and data collection processes were in Bahasa Indonesia, with translations into English by the authors. The 8E learning cycle model used in this study was developed by Ridwan and Rahmawati (2016) in an English version, taking participants through each stage of engage, explore, e-search, elaborate, exchange, extend, evaluate, and explain. Explanations of each stage were given in English and the process was explained in Bahasa Indonesia.
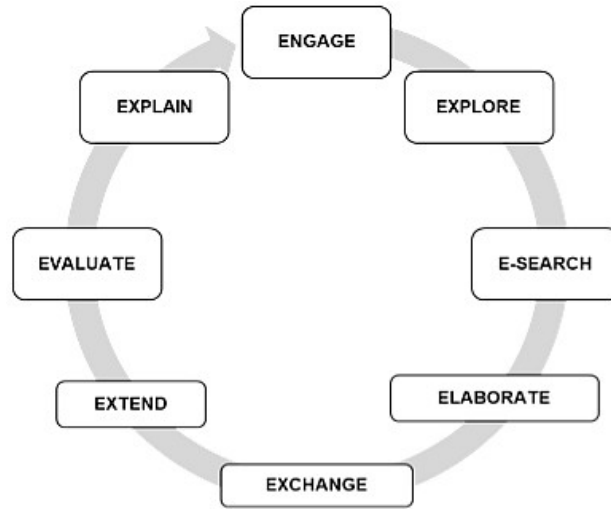

Figure 1: Stages in the 8E learning cycle model

There are three phases of learning in the 8E learning cycle. The first phase is personal learning, the second phase is social learning, and the third phase is reflection. The phases have been identified based on the characteristics of each stage.

Table 1: Learning activities through the 8E learning cycle

Phase	Stage		Activity
Personal learning	Engage	Understanding the issues	Stimulating students to use their own knowledge to understand the learning context through analysing the issues.
	Explore	Exploring prior knowledge	Students are required to solve problems in the issues using their prior knowledge.
	E-search	Exploring e-learning resources	Integrating ICT in exploring different information sources to solve problems.
	Elaborate	Construction of new knowledge	Elaborating prior knowledge with existing information after exploring learning resources.
Social learning	Exchange	Exchange ideas in knowledge construction	Students worked in groups and exchanged their understanding of the concepts.

Phase	Stage		Activity
	Extend	Reflection on their own understanding	Students are extending their understanding by reflecting on the development of their understanding after the collaboration.
Reflec-tions	Evaluate	Dialogue for developing new understanding	Students are reflecting on their understanding and connecting new understanding to the relevant concepts.
	Explain	Reflect on their prior knowledge with their new understanding	Students explain their new understanding at the end of the learning activity.

The pre-service teachers were given a worksheet which consisted of issues, concepts and questions to represent their understanding. An example of issues provided at the first stage (engage) is given in Figure 2.

The Unique Properties of Nanomaterials

Nanoparticles are the simplest form of structures with sizes ranges from 1 to 100 nm. Nanoparticles exhibit different properties than the bulk size. One of the nanoparticles commonly use is gold nanoparticles. Gold nanoparticles have different properties than gold in a bulk size. Gold is an unreactive material in a bulk size and widely used in the various field, such as jewelry, coin materials, dentistry, even in electronic devices. Gold in the bulk size is a metal with golden-yellow color, good electrical and thermal conductivity, corrosion resistant, and has high electrical conductivity. However, the different characteristics were shown by gold in the nanoscale. The color of gold nanoparticle depends on its size and shape. For example is gold nanoparticle that used in Rosace Nord stained glass at Cathédrale Notre-Dame de Chartres (France).

Red : Ag (~ 100 nm, Triangle)
Yellow: Au (~ 100 nm, Spheres)
Green: Au (~ 50 nm, Spheres)
Light Blue: Ag (~ 90 nm, Spheres)
Blue: Ag (~ 40 nm, Spheres)

Figure 1. Rosace Nord stained glass in Cathédrale Notre-Dame de Chartres (France), color change depends on the size and shape of gold and silver nanoparticles

Gold nanoparticles can exhibits different colors that can be used to colorize the Rosace Nord stained glass. This unique characteristics were caused by the size of particle. The different color of gold can be used to colorize the glass. The glass have a different color and it comes from the gold nanoparticle and silver nanoparticle in various size and shape. The color depends on the size and shape of nanoparticles. Besides the color of the gold nanoparticle, other properties of gold nanoparticle showed the different characteristic than a bulk, such as the reactivity and selectivity. Gold as an unreactive metal in a bulk can be a catalyst as nanoparticle which can increase the reaction rate. In the other hands, the gold nanoparticle can be used in the medical field as a drug delivery system. This application uses the unique characteristics of the gold nanoparticle to deliver the drugs to the cancer cell. Gold nanoparticle in the drug delivery system can control the release of the drug. Besides as a drug delivery system, the gold nanoparticle can be used as a biodetection and bioimaging.

Figure 2: The article for exploring the issue

After implementing the 8E learning cycle, the researchers looked at and interpreted the conceptual understanding of pre-service teachers in nanoscience and nanotechnology. Data were generated through a conceptual understanding test, in-depth interviews, classroom observations, reflective journals, and worksheets. Data was analysed through a process of coding themes found in all data sources.

Results and discussion

The Nanoscience and Nanotechnology course in this research is divided into three topics: the characteristics of nanomaterials, the physical properties of nanomaterials, and the chemical properties of nanomaterials. The results are presented below in two sections; the integration of the 8E learning cycle and pre-service teachers' conceptual understanding.

The 8E learning cycle

The 8E learning cycle started with *engaging* the pre-service teacher participants with issues in nanoscience and nanotechnology through an article covering the unique characteristics and properties of nanomaterials. At this stage, the participants explored their initial understanding to answer questions about the unique characteristics and properties of nanomaterials. Based on the results, the participants were interested in learning about nanoscience and nanotechnology through the issues covered in the article. This process helped them to engage in a new concept while promoting curiosity and eliciting their initial knowledge.

> I was interested when I read the article; the article provided me with a new insight about science nowadays that can be used for all aspects of life, such as health, food, and technology. However, after reading and exploring, I felt that my initial understanding was still not enough to explain the concepts of nanoscience and nanotechnology. This makes me want to know about nanoscience and nanotechnology.
> (*Participant 24's reflective journal, 8 November 2018*)

The statement above indicates that, by providing the issue at the engage stage, the participant has been helped to develop a motivation for *exploring* nanoscience and nanotechnology. Schwartz (2006) suggested this is because the chemical phenomena, facts, and principles were introduced, as needed, to inform the participants of the core issues to create the necessary context, so that the pre-service teachers' initial understanding of the matter could be determined.

After engaging the participants' prior knowledge, the 8E learning cycle provided an opportunity for them to access various learning resources from the Internet (*e-search*) to help them further understand concepts in nanoscience and nanotechnology. At this stage, they needed to expand on their prior knowledge using the results of their searching. Based on observations, the research indicated that at this stage the participants felt that they could develop or *elaborate* their understanding by exploring learning resources independently.

This learning encourages us to be able to use technology as a source of learning.
(*Participant 1, reflective journal, 1 October 2018*)

Honestly, I was lazy to read, then with this learning model it's like being told to read a
lot, write a lot, and have a discussion. At first, it felt like a burden. But it turned out to be
here, I got used to reading. So, in my opinion, the 8E learning cycle improves my
literacy. I want to use this learning model if I become a teacher.
(*Participant 14, in-depth interview, 1 October 2018*)

Based on the statements above, the participants also developed their ability to use
technology to find answers to the questions. This reflects Eilks and Byers' (2010) view
that the use of information and communication technology (ICT) in higher education
learning has developed rapidly over the past few years. This result indicated that
participants were motivated to learn with ICT because its use can create meaningful
learning opportunities and improve understanding (Dori, Rodrigues & Schanze, 2013).
Improved literacy skills supported the development of pre-service teachers' conceptual
understanding by increasing learning motivation, and by helping them to build their
cognitive structures, thereby improving their conceptual understanding (Guthrie et al.,
2004).

After participants augmented their understanding from different learning resources, they
were asked to *exchange* opinions and their understanding of concepts in nanoscience and
nanotechnology. During the discussion, all participants contributed ideas about the
concepts. Based on the observations made during this phase, participants felt that the
learning activities were fun because it involved the exchange of ideas during discussion.

Learning becomes fun and active by using the 8E learning cycle because we can explore
our initial abilities, discussions, and listen to our lecturers' explanations.
(*Participant 01, reflective journal, 1 October 2018*)

In the discussion, sometimes we have a different opinions and it make us respect
differences.
(*Participant 17, reflective journal, 25 October 2018*)

Participants stated that, in addition to improving pre-service teachers' soft skills, such as
collaboration, confidence, and respect to each other, an active learning atmosphere was
created. The participants faced the challenges of student-centred learning where they were
required to explore their own thinking and collaborate with others in constructing
knowledge. This stage provided participants with an opportunity to *extend*, to express their
opinions through discussion and to exercise their voices, which rarely happens in
classroom-based activities. Curiosity can stimulate a pre-service teacher to ask critical
questions so that they become more involved in learning through this stage (Rahmawati &
Koul, 2016). In addition, working together stimulated the participants' collaboration and
communication skills. Collaboration helped them complete the tasks within a supportive
environment (Blackley, Rahmawati, Fitriani, Sheffield & Koul, 2018). According to
Stodolsky (1984), when working in groups, students share goals using well-structured
assignments that help them to achieve learning outcomes. The use of collaborative

learning can encourage students to develop an appropriate view of concepts in chemistry (Shibley & Zimmaro, 2002; Stodolsky, 1984).

The last stages in the 8E learning cycle are *evaluate* and *explain*. In the evaluate stage, participants evaluated the understanding that they gained during their learning. The lecturer clarified and explained the concepts of nanoscience and nanotechnology that participants understood. The participants then evaluated the concepts against any misconceptions. The participants reported that conceptual changes were attained.

> This learning model was fun, I think it's like something new and made me realise that pre-service teachers in the university can also use the latest learning model. We have never gotten a learning model like this, and it turns out to be fun, even though I'm tired of writing. But honestly, because we wrote a lot, we read repeatedly, so we understand better. We felt that we have the preparation before lecturer's explanation and we can be more active in learning. So I understand better with this learning model compared to the models commonly used in another course.
> (*Participant 27, in-depth interview, 9 November 2018*)

Feedback of this kinds indicated that the participants engaged more in the course, as their prior knowledge was explored, and reflection on their individual and social learning helped them when the lecturer explained the concepts. The participants learnt new scientific terms that helped them connect their experiences to the scientific concepts being explored (Adesoji & Idika, 2015; Shaheen, Jumani & Kayani, 2015). The processes of reflection, collaboration, and evaluation throughout the 8E learning cycle engaged participants to become more active in their learning, and also more prepared to connect with new concepts. One advantage of the 8E learning cycle is that learning is carried out using student-centred principles. Students were active in constructing their understanding through the learning stages while the lecturer became the facilitator in the learning process.

In addition, the 8E learning cycle provided opportunities for participants to improve their conceptual understanding through collaboration and reflection. Collaboration during learning provided an opportunity for the participants to examine their beliefs about teaching and learning practices (Rahmawati et al., 2014). The research process put more emphasis than usual on practical (students' understanding) and emancipatory (students' empowerment) interests which benefited the participants' engagement during the lessons and possibly in their role as future teachers. This result is in accordance with Rahmawati & Taylor's (2018) findings, that it is important to be aware that when teachers focus only on achievement, they tend to ignore students' engagement and empowerment (Rahmawati & Taylor, 2018). Thus courses for pre-service chemistry teachers should focus not only on their achievement, but also on their engagement and how their understanding may be best developed.

Pre-service teachers' conceptual understanding

The participants' conceptual understanding in nanoscience and nanotechnology was elicited through questioning during the learning process using the 8E learning cycle, which

was then further examined by in-depth interviews and observations. Several participants had some prior knowledge about the concept, being able to explain the reasons for a material being classified as a nanomaterial, before the lecturer had explained the concept.

> Nanomaterials are materials measuring between 1-100 nm.
> (*Participant 27, worksheet at the engage and explore stage, 4 October 2018*)

As illustrated by the answer above, initial knowledge of nanomaterials was based on particle size. After using the 8E learning cycle, participants' understanding changed.

> Nanomaterials are materials between 1-100 nm and undergoing characteristic changes.
> (*Participant 2, worksheet at the evaluate and explain stage, 11 October 2018*)

Based on the worksheet answers, participants appeared to realise that, besides particle size, materials are regarded as nanomaterials because of their characteristics. Changes in these characteristics are caused by changes in size that have an impact on the surface area of the material's particles. This response is in accord with the theory that there is a clear size for this phenomenon. A change in the properties of materials in relation to particle size is more likely to happen below 100 nm size range, though changes may occur for some materials at sizes above 100 nm (Kreyling, Semmler-Behnke & Chaudhry, 2010). However, participants could not explain why the characteristics of nanomaterials can change. This participant did not mention the effect of size changes and the quantum effects:

> Nanomaterial is a material measuring 1-100 nm. The size of nanomaterial changes
> significantly so that it has unique characteristics. Because of its small size, the properties
> of the nanomaterial are affected by quantum effects. Electrons and other charge carriers
> have limited space in particles so that they have an impact on physical properties, such as
> conductivity, mechanical properties, optical properties, and magnetic properties. In
> addition, the size of the nanoparticles also affects the chemical properties (reactivity),
> because the smaller the particle size, the more the fraction on the surface, so the reaction
> can take place more quickly.
> (*Participant 27, worksheet at the evaluate and explain stages, 11 October 2018*)

Based on the answer above, this participant had a more appropriate conceptual understanding of how some characteristics may be affected by material size. Due to quantum effects, the properties of a nanomaterial may change significantly within the 1-100 nm range (Rao & Müller, 2006). The interview response below indicates a recognition of this:

> At first, I thought that nanoscience is a field to learn about small objects. I still imagine
> that small material is called "nano", but it turns out that in nanoscience, we learn about
> the material with a size of 1-100 nm and changes in properties. So I came to understand
> that a nanomaterial is unique because the changes in its size make the material have
> unique properties and that changes in characteristics were influenced by a quantum
> effect. Electrons and other charge carriers have limited space in particles because of their
> size. These size changes can be attributed to changes in band gap and changes in the
> energy level of the electron to split. That's a quantum effect and it affects the properties

of nanomaterials, such as conductivity, magnetic properties, optical properties, and chemical properties.
(*Participant 7, in-depth interview, 9 November 2018*)

Conceptual changes occurred when participants had an initial understanding that was not in accordance with the concept, and then during the learning process they had experiences where they were able to process, assimilate and accommodate their initial understanding. After participating in the 8E learning process, participants were able to use the new experiences to strengthen their existing knowledge (Abraham & Renner, 1986; Fosnot, 2013; Pritchard, 2009). The new experiences gained by the participants during the 8E learning process helped them build on their initial knowledge.

With physical properties, research participants had a simple initial understanding that nanomaterials have properties differing from the macro scale, with respect to conduction of heat and electricity, material strength, magnetic properties, and colour.

The behaviour of nanomaterials is very dependent on the size, shape, dimensions, and morphology of the nanomaterial.
(*Participant 12, worksheet at engage and explore stages, 20 October 2018*)

The response above indicates that the participant used initial knowledge from a previous topic. Participants could not explain the reasons for changes in properties. After carrying out learning using the 8E learning cycle, participants' understanding changed:

Electron movement in nanomaterials is limited and this causes different interactions of electrons with light, and may generate different wavelengths and colours in nanomaterial. When a material has a large energy gap, the wavelengths of absorption, transmission, and reflection change, and nanomaterials can be seen in colours differing from their bulk.
(*Participant 12, worksheet at the evaluating and explain stages, 20 October 2018*)

Changes in size to the nanoscale affect the physical properties of nanomaterials. This aligns with the theory that the different optical properties that occurred are the colour and wavelength of nanomaterials (Khan, Saeed & Khan, 2017). Because of the presence of the band gap in nanomaterials, properties such as electrical conductivity and magnetic susceptibility exhibit quantum size effects (Lu, 2013). Then band gap energy changes can explain other physical properties of nanomaterials, such as conductivity. The participants' conceptual understanding of conductivity properties is illustrated in the answer below.

The difference in nanomaterial conductivity is due to the electron energy gap difference. Electrical conductivity is influenced by the nanoscale due to changes in the band gap in the electronic structure along with decreasing material size.
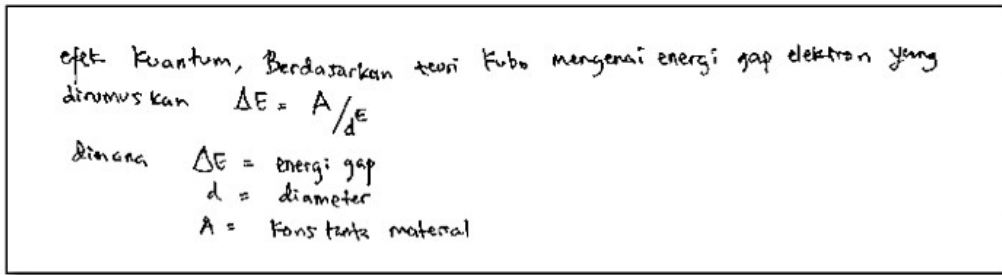(*Participant 17, worksheet at the evaluating and explain stages, 20 October 2018*)

Figure 3: Pre-service teacher's answer – the relation between size particle and band gap energy
(*Participant 32, worksheet at the stage of evaluating and explain, 20 October 2018*)
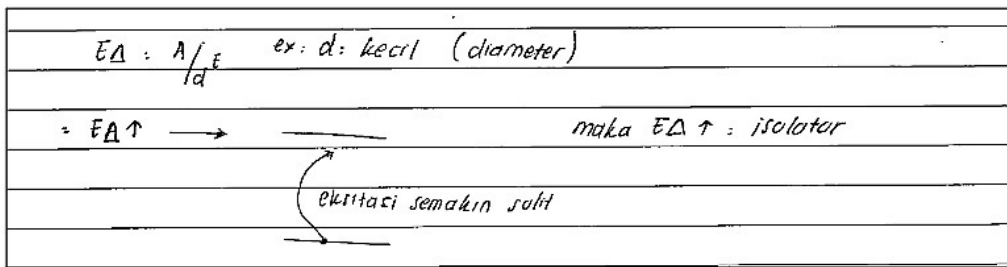

Figure 4: Pre-service teacher's answer – band gap energy in nanomaterial
(*Participant 07, worksheet at the stage of evaluating and explain, 20 October 2018*)

Based on the participants' explanation, the energy gap is influenced by size changes, making it difficult for electrons to occupy the conduction band. Participants tried to explain the effect of the band gap between the valence band and conduction band in accordance with the theory that states that for bulk materials, the atoms inside are far more than those on the surface (McConnell et al., 2000; Rao & Müller, 2006). Participants' conceptual understanding become more complex in explaining nanomaterial physics after using the 8E learning cycle in their course. They could explain the relationship between the physical characteristics in macro-sized material and nano-sized material. Their improved understanding of the physical characteristics of nanomaterial occurred because there was an initial understanding and learning process that occurred. During the 8E learning cycle, the pre-service teacher participants developed their knowledge that affected their understanding of the nanoscience and nanotechnology course.

Initial knowledge of chemical properties regarding the effect of size on the reaction ability of a material was already sufficient, as can be seen from answers below.

Nanomaterials become reactive because of the large surface area of the nanomaterial.
(*Participant 27, worksheet at the engage and explore stages, 28 October 2018*)

A participant's answers in the following interview regarding the chemical properties of nanomaterials showed an understanding of the effect of surface area on reaction rates:

Researcher: What causes reactivity?
Participant: That's the effect of surface area, the greater surface area, the greater chance of collision so that the reaction rate is faster or more reactive, as in my illustration.

Researcher: Okay, can you explain your answer?
Participant: Sure. Here's the explanation. Suppose there is a cube with 2 cm edges, meaning that the surface area is 24 cm², now, for example, the cube I divide to form 8 small cubes, with each edge 1 cm. If we count, the total surface area of the eight small cubes becomes 48 cm². Well, it means that the surface area is bigger, so that touch area becomes larger, so the reaction rate is faster. That causes the reactivity of the nanomaterial to be greater than the macro-sized material.
                 (*Participant 15, in-depth interview, 18 October 2018*)

Based on these answers, the participant can explain the small size of nanomaterials (1-100 nm) that caused nanomaterials to have a larger surface area, thus providing more surface to interact with other materials (Feather & Aznar, 2010). However, the participant could not explain the effect of shape on reactivity. Understanding the chemical reactivity of nanoparticles as a function of size and shape is a research area that is likely to lead to many useful and perhaps surprising results. For example, gold nanoparticles 3 nm in diameter are no longer 'noble' and can catalyse chemical reactions. The reactivity of gold depends on the size and shape of the gold nanoparticles (Rao & Müller, 2006; Schönborn et al., 2015). The pre-service teachers' initial understanding in this research enabled them to explain the chemical properties of nanomaterials which are highly reactive and are widely used as catalysts in chemical reactions. After using the 8E learning cycle process, the participants' responses indicated that they can understand several things that can affect the properties of nanomaterials as catalysts, namely the structure and band gap energy. This knowledge is based on interviews conducted after the evaluation process, and explanations that were completed.

Participant: After the implementation of the 8E learning cycle, my knowledge increased. I understand that the size of nanomaterial is not the only thing that causes nanomaterials to be a good catalyst. There are other factors.
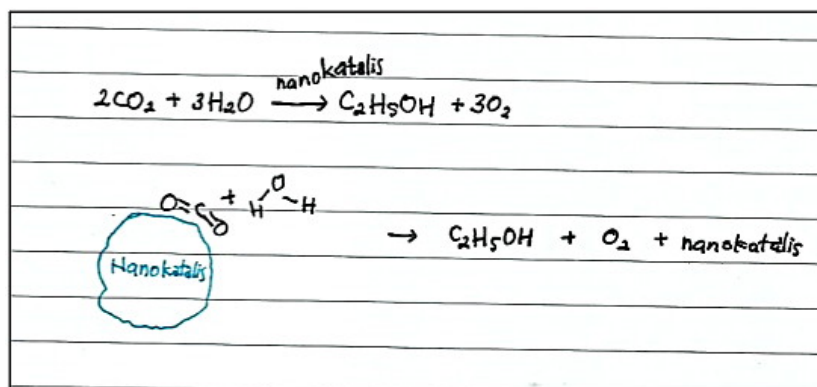
The nanomaterial shape and band gap energy, for example. If the band gap energy changes it will cause a change in the surface energy of the catalyst so that as the reactivity of the catalyst changes, so does the shape.

Researcher: Can you give an example of a chemical reaction with a nano catalyst?

Participant: I have read other example for nano-catalyst, it turns out there are a lot of chemical reactions that use nanomaterial as catalysts, for example, is the reaction of changes in carbon dioxide into fuel.

Researcher: Can you explain the reaction and the mechanism?

Participant: Of course.

$$2CO_2 + 3H_2O \xrightarrow{\text{nanokatalis}} C_2H_5OH + 3O_2$$

$$O=C + H\text{-}O\text{-}H \rightarrow C_2H_5OH + O_2 + nanokatalis$$

Nanokatalis

CO_2 is converted into fuel by reacting with H_2O. Nano catalysts plays a role in providing a place to react. CO_2 is trapped on the surface of the nano catalyst, making it easier for CO_2 to react with water so that fuel is formed, in the form of ethanol.

Researcher: What compounds or elements were used as catalysts in the reaction?

Participant: There are carbon nano tubes, metal nano catalysts, etc. I forget about the elements because each study developed a different type of catalyst with different efficiency, the percentage of product, the presence of side products, etc.

Researcher: Well, what can you get from that information?

Participant: I was impressed that it turns out that research is growing rapidly so it can be used for the current environment. If this research can be implemented, I think that environmental problems will decrease because the levels of CO_2 in the air can be reduced, which will reduce the impact of global warming. But we have to notice that plants needs CO_2 for photosynthesis, so the goal from the implementation of this research is to reduce CO_2 levels to reduce global warming.

Researcher: Wow, that's a good idea.

(*Participant 19, interview, 25 October 2018***)**

This explanation is in accordance with Lu (2013) who stated that the large surface area of nanoparticles has a straightforward positive effect on reaction rate and may also be a reasonable explanation of its catalytic activity. Structure and shape-based properties of any material at its nanoscale size can also affect the catalytic activity of a material. Participants realised that precisely controlling the size, shape, spatial distribution, surface composition, electronic structure, and thermal and chemical stability of the individual nanocomponents,

enables new properties and activity for use in catalysis. Key objectives of nano catalysis research could include increased selectivity and activity, low energy consumption, and long lifetime of catalysts by controlling pore size and particle characteristics (Philippot & Serp, 2012; Singh & Tandon, 2014). Based on answers in a test after using the 8E learning cycle, participant's understanding increased during their learning with the cycle. The participants can explain the concept of the unique characteristics in the physical and chemical properties of nanomaterials.

> Nanomaterials is a materials of which a single unit is sized (at least one dimension) between 1 to 100 nanometres. Based on this, the nanomaterial is classified into zero-dimension, one-dimension, two-dimension, and three-dimension nanomaterials.
> *(Participant 32, answer in a test regarding conceptual understanding of nanoscience concept, 10 January 2019)*

This participant's answer showed an appropriate understanding for classification of nanomaterials based on the dimensions of material in the nanoscale. In addition, participants could explain concepts about the unique characteristics of nanomaterials, for example as in the following answer.

> This significant change in size causes the unique characteristic properties compared to macro-size materials. Some properties that change are conductivity and reactivity. Change in conductivity caused by the change of particles to nano-sized, so the energy gap will be greater, and the conductivity of the material will be reduced for metal particles. While for reactivity changes due to the smaller particle size, the more surface area of the particles, so that the fields that can be used for a reaction increase. In addition, various shape of nanomaterial also affect the reaction ability of the nanomaterial.
> *(Participant 32, answer in a test regarding conceptual understanding of nanoscience concept, 10 January 2019)*

Besides understanding about changes in surface area, pre-service teachers also understood shape and band gap energy effects in nanomaterials. Furthermore, they could learn from many different resources and find more examples that are relevant. Their understanding was obtained after using the 8E learning cycle which encouraged active learning. The 8E learning cycle ensures that pre-service teachers can construct understandings based on their experiences at each stage of the cycle. Understanding of these concepts is expected to help them to develop their competencies, especially in delivering their knowledge as teachers. Their improved understanding can improve their competencies with chemistry concepts and applications in nanoscience and nanotechnology. In addition, as pre-service chemistry teachers, they can improve their learning about pedagogical aspects and their ability to use the 8E learning cycle upon becoming teachers of chemistry or science in secondary schools.

Conclusion

The results show that the 8E learning cycle engaged pre-service teachers in developing their conceptual understanding of nanoscience and nanotechnology by utilising a process

of collaboration, discussion, and reflection. Exploration of the initial understanding engaged their curiosity and an incentive to search for the right concepts, by using different learning sources at the e-search stage. They developed their understanding of the concepts of the unique characteristics in the physical and chemical properties of nanomaterials which, in turn, developed their competencies in teaching the nanoscience and nanotechnology concepts in their future roles. In addition, they also engaged with current issues in using nanoscience and nanotechnology - issues arising from the unique characteristics and different properties of nanomaterials that enable applications that are not possible in macro size. Differences such as colours of gold nanoparticles compared with gold in bulk, nanomaterials as a catalyst, gold nanoparticles as a drug delivery system, and carbon nanotubes as a material with better conductivity than other metals. In the last stage of the research, pre-service teachers engaged with the lecturer's explanations of correct concepts in nanoscience and nanotechnology. The lecturer facilitated the development of pre-service teachers' conceptual understanding of nanoscience and nanotechnology, for example understanding how quantum effects may change significantly within the size range 1-100 nm.

In addition, pre-service teachers were able to explain the chemical properties of nanomaterials which are widely used as catalysts in chemical reactions. They realised that by precisely controlling the size, shape, spatial distribution, surface composition, and electronic structure and thermal and chemical stability of individual nanocomponents, they can be used in catalysis with new properties and activity. An improvement of pre-service teachers' conceptual understanding was obtained through activating their initial understanding, and their use of digital literacy, discussion, lecturer's explanation, and self-reflection at each stage of the 8E learning cycle. They also learnt to exchange their ideas during the collaboration phase, which helped them in developing more effective communication with their colleagues, to deliver their ideas and to respect different perspectives. The experience developed their content knowledge and their social skills. The 8E learning cycle model can provide good learning experiences for pre-service teachers, using the principles of active learning in every stage, so this model can be a reference for pre-service teachers to develop in their future classroom teaching. Furthermore, this model can be implemented in other science and in non-science subjects, to develop students' conceptual understanding, overcome misconceptions, and acquire social skills.

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