Model of educational reconstruction of solid state chemistry: Students’ view of nature of science and technology

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Abstract. Develop an adequate conception of the NOST is one of the goals in science education. A good conception of nature of science and technology (NOST) is related with how students understand and perceive science concept. Solid state chemistry is one of science concept that has many applications in daily life and advance technology. Unfortunately, this concept is containing abstract concept. Therefore, need an effort to make it easily understood by students. Model of educational reconstruction (MER) is adopted to define learning design in order to make a connection between concept and its applications based on students’ and scientists’ conceptions. Students’ view of NOST is analyzed before and after intervention. Their conception about NOST are categorized into realist (R), has merit (HM), and Naïve (N). The majority of students held R view of the target NOST aspects after the intervention. These results showed that learning based on MER could support to develop students conception of NOST.

1. Introduction
Develop an adequate conception of the NOST is one of the goals in science education [1]. A good conception of NOST is related with how students understand and perceive science concept. Several studies have examined the students’ view of the NOS aspect. Generally the conception of respondents is in the naive category, they do not have a good knowledge of NOS aspects [2]. In addition, respondents who have good knowledge of the NOST aspect also have not been able to make good decisions in determining the science and technology based on current issue [3]. Meanwhile, previous researches on NOS were limited to analyzing respondents’ conceptions of NOS or developing the instruments [1-4]. Therefore, it is necessary to develop a science lesson that can equip students about the NOST aspect.

Solids state chemistry is one of the science topics that are composed of metallic, ionic, molecular, and covalent network crystal. It concept contains basics concept are like metallic, ionic, and covalent bonding that known as abstract concept and causes the students to have difficulty in learning it [5-12]. Meanwhile, students find many applications of solid state chemistry concept in daily life and advance technology.

Context phenomena lesson is closely related to advanced technology and the current time issues are used to motivate students in learning solid state chemistry in order to make the concepts easily
understood by students. To make it comprehend, MER is adopted to define a learning design. MER is a Germany didactic tradition developed as a framework for learning a concept or scientific knowledge based on students’ and scientists’ conception [13]. Considering the students’ conception in designing learning has a good effect in learning [14-18] because students will realize about their conception.

Through MER, after analyzing students’ and scientists’ conceptions, students are asked to analyze the contexts phenomena; infer data in making conclusions; integrate previous knowledge with new knowledge through discussions and scientific explanations; evaluate the theories to predict the properties and application of concepts in more complex context in order make knowledge remain stable. The modern context is used in this research to make it easy for students to connect the content they learn with applications in daily life and advance technology.

Modern context is expected to enhance students' views of NOST aspects. To identify students' views of NOST, there are five NOST aspects developed in the study [19]. Regarding to the importance of NOST aspect in science learning, the purpose of this study is to examine the use of MER in developing students’ view of NOST.

2. Method

2.1. Participants and settings
Participants involved in the study were 33 pre-service chemistry teachers who taking an inorganic chemistry course at one state university in Serang-Banten. Research setting is one group pre-test and post-test experimental design.

2.2. Learning design
The learning used three relevant adopted phases of MER: (1) clarification of science conceptions, (2) investigation in students’ conception, (3) developing teaching-learning sequence as described in figure 1. It show the learning design is start from analysing scientists and students’ conceptions, character of solid state chemistry concepts, and analysing the chemistry learning objective.

Figure 1. Learning design adopted MER.
All of the results are taken as a consideration to determine phenomena and context applications in learning that known by students in daily life and advance technology in order to make a relationship between students’ conceptions and its application. All the elements in learning are designed by students’ need. Learning is supported by laboratory experiment. Experiment was conducted as a modern context application of solid state chemistry topic. There are two main experiments conducted by the students. First, doping material to produce conductive materials by making glass and polymer conductive, both materials then used as material to design DSSC experiment. The second one is simple graphene fabrication experiment. Those experiments were conducted to evaluate the theory and predict the material properties.

2.3. Instrument
The instrument of this study was questionnaire. This questionnaire is aimed at analysis students' views of NOST before and after interventions. There are five NOST aspects developed that consist of: 1) character of science and technology, 2) science objective and scientific research, 3) characteristics of scientific knowledge and theory, 4) ways of acquiring scientific knowledge and theory, and 5) the relationship of science and technology. These five aspects are implied in 9 multiple choices questions. Each option on the multiple choices describes the view of NOST.

2.4. Data analysis
Questionnaires of students' views of NOST were analysed and categorized into three categorize as follows; 1) Realist (R) is a group of statements that show the actual conditions and in accordance with the general view, concepts and theories of science; 2) Has merit (HM) is a group of statements that show conditions that are not entirely true but there is a part of the statement still in accordance with the general view, concepts and theories of science; 3) Naïve (N) is a view that is totally unrelated to the concepts and theories of science or students do not have enough knowledge to make choices.

3. Result and discussion
3.1. Students’ activities in learning process based on MER
Solid state chemistry learning is designed based on MER [13] to get adequate knowledge, view of NOST aspect, and consider students’ need in order to make a correlation between content and context application. Modern contexts are chosen in order to make learning is interesting and challenging. Making a pattern of context-content-context is modified of the students’ worksheet. There are three worksheets, consist of metallic crystals, ionic crystals, and covalent network.

Jewelry, cable wires, and statues are presented in metallic crystal context. LED (light Emitting Diode) is presented as modern contexts. This worksheet is equipped with laboratory activities (conductive glass and polymer). Glass and polymer materials are known as insulators by students. Through this experiment students are required to think critically how the insulator material is converted into a conductor. Students should be able to explain and predict these properties using a particular theory. The modern applications of conductive glass and polymers are Dye Sensitized Solar Cell (DSSC) experiments.

Ceramics are context applications of ionic crystals. Graphene application is context of covalent network. Students are asked to analyze the graphite structure and then to design graphene from graphite. Students analyze the graphene advantages and applications in the future compared to graphite. All students’ engagement on learning process is presented in table 1. It shows that through the context, students could recognize the modern application of the content. Students are able to link the chemistry contents are learned with relevant issues in their life. This is in line with the results of Bulte's [21] research that learning using an authentic context is able to complete the principles of need coherent, need to know and based on authentic practice. Thus, future expectations through contextual learning, students can participate in community discussions about science and technology applications.
Table 1. Students’ engagement on learning process.

| Metallic crystal                          | Ionic crystal                      | Covalent network                           |
|------------------------------------------|------------------------------------|--------------------------------------------|
| **Mapping a content and relating its properties and applications** | **Mapping a content and relating its properties and applications** | **Mapping a content and relating its properties and applications** |
| **The questions are related to:**        | **The questions are related to:**   | **The questions are related to:**          |
| a. Metals and its properties             | a. Application of ionic crystal    | a. Diamond, graphite and graphene applications |
| b. Alloys and its properties             | b. Structure and properties of ionic crystals | b. Diamond, graphite and graphene structures |
| c. Materials that have same electrical properties |                       |                                            |
| **The hypothesis are:**                  | **Electrical property is caused by electrons or ions delocalization** | **a. Graphene has a good conductivity than graphite** |
| a. There are materials that have electrical properties same with metals. |                       | b. Diamond is insulator                   |
| b. Alloys are made by substitution and addition |                       | c. Graphite is soft in opposite diamond is hard |
| c. Metals and its alloys have same properties |                       | d. Graphite could transform to become graphene |
| d. Metals and its properties have different properties |                       |                                            |
| **The investigations are:**              | **Electrolyte test**                | **The investigations are:**                |
| a. Test the properties (mechanical, physical, and electrical) of metals and its alloys |                       | a. Conductivity test                      |
| b. Make an alloy                         |                       | b. Fabrication of graphene                |
| c. Electrolysis                          |                       |                                            |
| d. Synthesize a materials in order have same electrical properties as metals |                       |                                            |
| **Hands on activities**                  | **Investigation content thorough multimedia** | **Investigation content thorough multimedia** |
| a. Conductive glass                      |                       |                                            |
| b. DSSC                                   |                       |                                            |
| c. Conductive polymer                     |                       |                                            |
| d. Investigation content thorough multimedia |                 |                                            |
| **Data are Inferred**                    | **Students answer about the content application related to context** | **Students answer about the content application related to context** |
| a. Students have to analyze the modern context (LED) |                       | a. Students have to analyze the modern context (Graphene) |
| b. Mapping a content and relating its properties and applications |                       | b. Mapping a content and relating its properties and applications |

In this issue-based learning student is involved in connecting a theory with the applications, conducting experiments, conducting investigations and inference experimental data. So it is hoped that through this learning will help realize the goal of science education that are to help students develop a sufficient conception about NOST aspect and also develop student literacy ability [1].

3.2. Students’ view of nature of science and technology
There are five students' point of view about science and technology which were known as NOST aspects. Five NOST aspects are analyzed through questionnaire. Each statement put forward in each
questionnaire that was grouped into R, HM, and N. The number of students giving views across the three categories was then dissertated (table 2).

Table 2 shows that after intervention, students view of NOST mostly in R category. Engaged in learning process make students realize that nature of science is a systematical investigation process to produce a knowledge. As Gardner [22] said that science is a special tool to investigate a question. While investigating, hypotheses have been made; data are collected, and made a conclusion based on data. 100% of students before and after intervention are in R category, they define science knowledge is the most appropriate interpretation and approved by scientist. Students are accustomed to using theory as their guide in conducting research. As stated by Temel [1] and Lederman [4] that theory is used to construct research questions and guidance to do further research.

| No | Aspect of NOST                      | Instrument                                                                 | Respondent (%) | Respondent (%) |
|----|-------------------------------------|----------------------------------------------------------------------------|----------------|----------------|
| 1  | Character of science and technology | (1) and (2) Definition of science<br>(6) Definition of science knowledge/theory<br>(7) Definition of technology<br>(3) Purpose of science | 6 18 1<br>100 48 2<br>3 23 2<br>48 15 2 | 18 16 1<br>100 45 0<br>9 21 1<br>54 17 3 |
| 2  | Purpose of science and scientific research | (5) Definition of scientific research<br>(4) History of scientific research | 46 3 0<br>58 12 1 | 48 0 0<br>42 18 0 |
| 3  | Characteristics of scientific knowledge and theory | (9) Scientific process<br>(8) Relationship of science and technology | 11 15 0<br>58 37 1 | 12 15 3<br>64 41 1 |

To define technology, students think that technology is an application of science in order to improve utilization a tool (HM Category). In order students in Real category they think that technology is a process to produce a tool, or a process to produce, develop, and design a tool and scientific instruments. Modernizing the context of science materials in MER-based learning such as LED context, Conductive Glass, conductive polymers, DSSC, and graphene helps students to see the relationship and role between science and technology.

Science always relates to technology and education has a major role to make it clear. The results of this study indicate that learning developed based on modern issues and technology is able to develop students' conceptions of the relationship of science and technology. Students are able to design, create, develop and test materials such as tools and scientific instruments. It is a basic view to tell to students that science knowledge always based on empirical data [23]. The other studies show the opposite, students showed no interest to make a decision of technology aspect even though they have a good science concept [3]. This suggested learning that emphasizes concepts is also capable of develop students' views of NOST aspects.

4. Conclusion
Improving students’ view of nature of science and technology is one of a goal of science education. A good conception of NOST is related with how students understand and perceive science. Solid state chemistry is one of science concepts that have many applications in daily life and advance technology. Through learning it concept, students get a chance to have good conceptions about NOST aspects. Model of educational reconstruction (MER) is adopted to define learning design in order to make a connection
between concept and its applications, based on students’ and scientists’ conceptions. The modern context application is used to make students are able good understanding about character of science and technology, purpose of science and scientific research, character of scientific knowledge and scientific theory, acquire scientific knowledge and scientific theory, and relationship of science and technology. Majority of students held R category view of the target NOST aspects. The results showed that learning based on MER could support to develop students conception of NOST.

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References
[1] Temel S, Sen S and Ozcan O 2017 Res. in Scie & Tech. Edu. pp 1-14
[2] Dogan N and El-Khalick F 2007 Res. in Sci & Tech. Edu. 45 pp 1083-1112
[3] Bell R L and Lederman N G 2002 The Nauture of Science and Decision Making. Pp 352-377
[4] Lederman NG, El-Khalick F, Bell R L and Schwartz S R J. of Res. In Scie& Teach 39 pp 497-521
[5] Bergqvist A and Chang Rundgren S N 2017 Res. in Sci & Tech. Edu. 35 pp 215-237
[6] Bergqvist A, Drechsler M and Chang Rundgren S N 2016 Int. J. Sci. Edu. 38 pp 298-318
[7] Bergqvist A, Drechsler M, De Jong O and Rundgren S N C 2013 Chem. Edu. Res and Prac J. 14 pp 589-606
[8] Croft M and de Berg K 2014 Scie & Edu J. 23 pp 1733-1761
[9] Dhindsa H S and Treagust D F 2014 Chem. Edu. Res and Pract. J. 15 pp 435-446
[10] Nimmermark A, Öhrström L, Mårtensson J and Davidowitz B 2016 Chem. Edu. Res and Pract J. 17 pp 985-1005.
[11] Pérez J B, Pérez M B, Calatayud M, García-Lopera R and Sabater J 2017 Asian J. of Edu. and e-Learning 5
[12] Sen S and Yılmaz A 2017 J. of Turkish Sci. Edu. 14
[13] Duit R, Gropengießer H, Kattmann U, Komorek M and Parchmann I 2012 The Model of Educational Reconstruction—a Framework for Improving Teaching and Learning Science Scie. Edu. Res and Pract in Europe (Springer) pp. 13-37
[14] Grillenberger A, Przybylla M and Romeike R 2016 ISSEP 2016 31
[15] Reinfrid S, Aeschbacher U, Kienzler P M and Tempelmann S 2015 Int. Res in Geo and Env. Edu 24 pp 237-257
[16] Saarelainen M, Hirvonen P E and Asikainen M 2009 Lat. American J. Phy. Edu. 3 pp 518-526
[17] Sam A, Niebert K, Hanson R and Aryeetey C 2016 Int. J. Acad. Res and Refl. 4 pp 54-64
[18] Sam A, Niebert, K, Hanson R and Twumasi A K 2015 Int. J. Acad. Res and Refl. 3 pp 67-77
[19] Tairab H H 2001 Res. in Sci & Tech. Edu. 19 pp 235-250
[20] Rubba P A and Harkness W J 1996 Int J. Sci. Edu. 18 pp 387-400
[21] Bulte A M et al 2007 A research approach to designing chemistry education using authentic practice as context. 28 pp 1064-1086
[22] Gardner Paul L 1994 Int. J. of Tech & Des. Edu. pp 123-153
[23] Bybee Rodger W 2006 Scientific Inquiry and Science Teaching. Scientific Inquiry and Nature of Science (Springer) pp. 1-14