Ionic liquids in chemistry teacher education: An interactive simulation on their fundamental structure-property relationships

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Abstract. This research was conducted to reconstruct the activities of technochemistry education through interactive simulations of the relationship between structure of ionic liquids with their physico-chemical properties. This simulation was constructed to enhance the chemistry teacher students’ ability of the view of the nature of science and technology (VNoST). Ionic liquids were chosen as a technochemistry model because in this materials; the structure, properties and their performance can be connected to one another easily and attractively. By engineering its cation and anion structure, the properties of ionic liquids can be adjusted (tailored-made materials) to the needs of the engineer. Technochemistry education views education from the perspective of engineers and scientists who work not only on inquiry, but also on the perspective of engineering and design. The research was conducted to overcome the problem of the low performance of Indonesian students' scientific literacy as revealed in the PISA (Program for International Student Assessment) study from 2000-2015. The weak performance of scientific literacy of students can be caused by weak understanding of the teacher of the nature of science and technology or View of Nature of Science and Technology (VNoST), a core component of scientific literacy. Reconstruction of technochemistry education activities carried out is directed to produce interactive simulation software for the engineering of ionic liquids structures. The method used in this research is Research and Development (R&D) through the Model of Educational Reconstruction (MER). The first stage is analyzing, clarifying, and reconstructing the structure of scientific content (scientific explanation) into a content structure suitable for learning (pedagogical explanation). The next stage of analysis studies related to students' pre-conceptions on the reconstructed topic. In the final stage, the teaching-learning process is implemented using the software produced and reflects the results of the implementation for the improvement process through a quasi-experimental study. Based on the results of the implementation, this interactive simulation has the potential to enhance students' VNoST abilities. This is indicated by the more students who have the Realist category in six of the eight questions on the existing VNoST aspects.

1. Introduction
The demands of life today make everyone aware that people living in the 21st century must be equipped with a variety of thinking skills. The study of scientific literacy assessment at PISA (Program for International Student Assessment) of Indonesian students shows results that seem inconsistent with this demand. The performance of scientific literacy of Indonesian students in 2000-2015 is still at a low
level. The 2015 study for example shows that only 1.6% of students can work effectively with situations and problems that might involve explicit phenomena that require them to make conclusions about the role of science or technology [1].

Vesterinen, et al. [2-4] and Tala, et al. [5,6] suggested that efforts can be made from the teacher to mastering the nature of science and technology (Nature of Science and Technology, NoST), the main and important elements of scientific literacy. Science teachers who do not understand NoST will find it difficult to teach and assist students in gaining a good understanding of science concepts [7]. According to Tala, et al. [5,6] and Chamizo [8,9], to build a better understanding of NoST, technoscience education activities can be carried out. Technology can not only provide an understanding of the regularity of physical and chemical phenomena but also gives the ability to create phenomena and design ways to control, manipulate and engineer them.

In this research, ionic liquids was chosen as a technochemical model for various reasons, mainly because in this material its structure, properties and performance can be easily connected, manipulated and engineered. Manipulation and engineering in the structure of ionic liquid materials will result in changes in material properties that will affect its function and utilization. By engineering its cation and anion structure, the properties of ionic liquids can be adjusted (tailored-made materials) to the needs of the engineer. Ionic liquids are materials that only consist of ionic species (cations and anions), do not contain certain neutral molecules, and have relatively low melting points (<100-150 °C). This relationship provides an illustration of the potential for the application of technochemical activities in manipulating the structure of a material to produce different material properties so that chemistry teacher students can understand the relationship of science and technology in engineering a product.

In the technochemistry education, models and modelling have an important role, especially in explaining scientific concepts. Chamizo [8,9] holds that the model does not only function as a representation, but also as a medium for intervention and engineering by manipulating the model. The model to be used is an interactive simulation because in addition to being able to integrate several models and animations to represent complex processes or natural phenomena [10], it also allows users to interact with images by utilizing available features [11]. The existence of features that allow users to interact can be a potential to carry out engineering activities to foster understanding of NoST. Research on teaching and learning about ionic liquids that has been carried out is directed more towards the development of practical models in the laboratory, not yet directed to the development of simulations and their implications for student’s View of NoST.

2. Methods

The study was conducted based on research design which can be illustrated in Figure 1. This diagram is an adaptation of the Model of Educational Reconstruction [12,13]. Figure 1. shows that to reconstruct ionic liquids as a learning topic, scientist conceptions and students pre-conceptions correlate with designing effective teaching and learning activities (see Figure 1). Scientists conceptions (1) are extracted from scientific textbooks and journal articles through the QCA (Qualitative Content Analysis) [14]. Conception of the most students (2) of the ionic liquids, their structure and properties; and their performance was taken through the study of empirical clinical interview of the 22 students in Bandung. Results of clinical interviews were also analyzed using QCA (Qualitative Content Analysis) [14]. Based on the conception studies of scientists and students, interactive simulations (3a), learning environments (3b) and their assessments were developed through the VNoST (View of Nature of Science and Technology) questionnaire [15].
3. Results and discussion

3.1. Scientists' conception

Literatures (books and journal articles) related to the ionic liquids was used to perform content analysis to get the scientist's conception of the ionic liquid [16-18].

Here are the results of content analysis of the literature that produces scientific conceptions related to ionic liquids, the relationship of structure and properties, and their performance.

Table 1. The results of content analysis of scientific conceptions related to ionic liquids, the relationship of structure and properties, and their performance.

| Basic Relevant Concepts of Chemistry | Content Analysis Results                                                                 |
|-------------------------------------|--------------------------------------------------------------------------------------------|
| Ionic Solids                        | Ionic Liquids, Ionic Liquids and Liquid Salt                                               |
|                                    | Ionic liquids are materials that consist only of ionic species (cations and anions), do     |
|                                    | not contain certain neutral molecules, and have a relatively low melting point, located    |
|                                    | at temperatures <100-150 °C, although generally at room temperature. In contrast to        |
|                                    | molten salt which usually has a high melting point and viscosity, it is also highly        |
|                                    | corrosive, ionic liquids are generally liquid at room temperature, have relatively lower   |
|                                    | viscosity and have relatively non corrosive properties. Ionic liquids have a very wide     |
|                                    | liquid range; nonvolatile; non-flammable); high thermal, chemical and electrochemical      |
|                                    | stability (in some cases have thermal stability up to 400 °C); negligible vapor pressure;  |
|                                    | the ability to dissolve many organic and inorganic compounds; and miscibility which        |
|                                    | varies with water and organic solvents.                                                   |
|                                    | The properties of ionic liquids can be adjusted by changing the structure of the cations   |
|                                    | and anions. The properties of ionic liquids such as thermal properties, electrochemical    |
|                                    | stability, ionic conductivity, and viscosity that can be regulated depending on the        |
|                                    | cations and anions that make them ionic liquids are known as tailored-made solvents.       |
|                                    | Ionic solids generally are fragile compounds with a high melting point, form crystalline   |
|                                    | solids. These properties result from the electrostatic force which maintains the ions in a  |
|                                    | rigid and well-arranged three-dimensional arrangement, as shown in Figure 2.              |
Figure 2. Structure of the crystal solids of ionic sodium chloride.

The results of the content analysis in the table 1. show that the topic of ionic liquids contains basic concepts of chemistry that are relevant to the learning needs of prospective chemistry teacher students.

3.2. Students’ pre-conceptions
Following are the results of the content analysis of the results of clinical interviews with 22 students (11 students from fourth semester and 11 students from sixth semester) that produced students' pre-conceptions of ionic liquids, the relationship of structure and properties, and their performance.

Table 2. The results of content analysis of students' pre-conceptions related to ionic liquids, the relationship of structure and properties, and their performance.

| Concept Label | 4th Semester Students | 6th Semester Students |
|---------------|-----------------------|-----------------------|
| Get to know ionic liquids | The majority of students consider ionic liquids as melting inorganic salts, inorganic salts and electrolyte solutions in the body which are actually isotonic drinks. | |
| Distinguish and explain molten inorganic salts and ionic liquids | 70% of fourth semester students can answer that the two salts can be distinguished from their structure | 80% of the sixth semester students said that apart from the structure of the two salts, they were distinguished from their cationic and anionic form so as to form an asymmetrical bond. |
| Factors affecting the melting point differences in inorganic salts and ionic liquids | most respondents can explain that differences in the structure and strength of bonds that occur in ionic salts and ionic liquids that affect the melting point of these salt compounds. | Sixth semester students add that the types of cations and anions are not symmetrical, causing bonds to be less strong and have a low melting point. |

The results of preconceptions of chemistry teacher students, both in the fourth and sixth semesters, show that only some students are able to explain their knowledge of chemical content related to the ionic liquid context based on a scientific perspective. Most students are not familiar with ionic liquids and their applications in chemical technology. Students can predict any chemical content related to the context of ionic liquids.

3.3. Implementation study results
Following are the results of an implementation study of 22 students (11 students from fourth semester and 11 students from sixth semester) that produced a VNoST student achievement map using an interactive simulation that had been developed.
### Table 3. Results of interactive simulation implementation studies on students’ VNoST.

| Nr. | VNoST Aspects                  | VNoST Aspects                  | Sub | 4th Semester (%) | 6th Semester (%) |
|-----|--------------------------------|--------------------------------|-----|------------------|------------------|
|     |                                |                                | Sub | R    | HM   | N    | R    | HM   | N    |       |
| 1   | Characteristics of Science and | Definition of Science          |     | 39   | 49   | 12   | 37   | 58   | 5    |       |
|     | Technology                     | Scientific Knowledge           |     |      |      |      |      |      |      |       |
|     |                                | Technology                    |     |      |      |      |      |      |      |       |
| 2   | The Purpose of Science and     | The Purpose of Science         |     | 51   | 29   | 19   | 70   | 18   | 12   |       |
|     | Scientific Research            | Science                        |     |      |      |      |      |      |      |       |
| 3   | Characteristics of Scientific  | Definition of Scientific       |     | 87   | 2    | 3    | 8    | 90   | 2    | 5    |       |
|     | Knowledge and Scientific       | Research                       |     |      |      |      |      |      |      |       |
|     | Theory                         | Background of Scientific       |     | 46   | 44   | 10   | -    | 47   | 48   | 5    | 3    |
|     |                                 | Research                       |     |      |      |      |      |      |      |       |
| 4   | How to Acquire Scientific      | Scientific                     |     | 19   | 58   | 1    | 18   | 75   | 5    | 1    |       |
|     | Knowledge and Scientific       | Research Process               |     |      |      |      |      |      |      |       |
|     | Theory                         |                                 |     |      |      |      |      |      |      |       |
| 5   | Relationship of Science and    | Science,                       |     | 43   | 55   | 2    | 50   | 48   | 2    |       |
|     | technology and social relations|                                 |     |      |      |      |      |      |      |       |

The view of chemistry teacher students towards NoST shows that most choose statements that indicate conditions that are not entirely true, but there are parts of statements that are still in accordance with the general view of science and in accordance with science concepts and theories with Has Merit category. This shows that VNoST students still need to be improved, but the interactive simulations can help answer the questions in the VNoST questionnaire.

### 4. Conclusions
Interactive simulations made based on strategic steps to overcome the weaknesses of VNoST students have the potential to build students’ VNoST abilities. This can be seen from the data of interactive simulations showing six of the eight categories in the VNoST aspect, more students have a Realist category. Although based on the results of the interview stated that in answering VNOST questions based on personal opinions, the confirmation results stated that interactive simulations can help answer the questions in the VNOST questionnaire.

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