Pre-service chemistry teachers’ learning obstacles in understanding the relationship between the chemical structures and physicochemical properties of ionic liquids

D M Venessa1*, Hernani2 and H S Halimatul2

1 Masters in Chemistry Education, Postgraduate School, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia
2 Department of Chemistry Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No 229, Bandung 40154, Indonesia

*Corresponding author’s email: dy2psihite@gmail.com

Abstract. The purpose of this study was to determine the difficulties faced by pre-service chemistry teachers in correlating the structures with the physicochemical properties of ionic liquids. The descriptive research method used quantitative and qualitative approaches. The participants in this study were 23 pre-service chemistry teachers from one of the universities in Indonesia. Data collected using an instrument in the form of a description test guided by the discourse on ionic liquid technology. In general, the results of the study indicate that more than half of the students have difficulties in applying chemical concepts related to the context of the relationship of structures with the physicochemical properties of ionic liquids. The result also reveals that the most dominant difficulty experienced by pre-service chemistry teachers is difficult to determine the right chemical concepts to explain the tendency of melting point differences of molten salt and ionic liquids. The results findings will be used as the basis for developing didactic designs that are oriented to resolve learning obstacles by pre-service chemistry teachers in understanding the relationship of structures with physicochemical properties of ionic liquids.

1. Introduction
Chemistry is a part of science that studies how natural material can change from a structure to another structure with certain properties [1]. Chemistry is one of the most important branches of science and has been considered a difficult subject [2]. Most of the chemical concept is considered as abstract, sequential, hierarchical, and complex [1, 3]. Difficulties are influenced by conventional learning where students learn a lot about concepts, principles, and theories without involving the concept of a chemical process. Conventional learning processes cause a lack of opportunities for students to build a proper understanding of concepts, principles and chemical theory [1].

Research on pre-service chemistry teachers’ conceptions has become a major concern because many students have misconceptions about chemical concepts even after years of teaching [4, 5]. Difficulties or misunderstandings owned by pre-service chemistry teachers should be a point of attention in research as a basis for the development of learning designs that refer to problems experienced by students. Pre-service chemistry teachers’ initial understanding of the concept of chemistry must be taken into account at the beginning of teaching [5] so that they have the right understanding in implementing the chemical concepts to a phenomenon or chemical context that is developing at this time. As expressed by Ausubel
[6], new knowledge must be linked to prior student knowledge to produce meaningful learning. Knowledge is uniquely built by each individual or student to understand the world [7] especially in understanding the relationship between science and technology. Likewise, as suggested by Hunt and Minstrell in Ozmen [8] that difficulties in science occur because the conception of students before teaching is not taken into account so that communication barriers between educators and students cannot be overcome. Therefore, learning obstacles or difficulties experienced by pre-service chemistry teachers should need to be considered in learning so that effective teaching interventions can be produced for meaningful learning [5].

Several studies on the analysis of pre-service chemistry teacher difficulties have been conducted. Research conducted by Dindar et al. [9] shows that students have some difficulties when integrating chemical concepts in context or integrating them into other fields. Similarly, research conducted by Taber [10] by developing interview questionnaires to explore the extent of conceptual integration in students who study chemistry and physics in higher education. From the results of his research, Taber [10] concluded that students had some difficulties in integrating chemical concepts. Epistemologically, the difficulties of pre-service chemistry teachers occur because of the limited context known to students. In this case, students only receive partial conceptual understanding so that when faced with a different student context with difficulty in using it.

Analysis of the difficulties or barriers to learning of pre-service chemistry teachers needs to be done. In addition to producing effective learning designs, this has a very direct and indirect effect on the teaching of pre-service chemistry teachers later [11]. They have an important role in directing students to use conceptual knowledge in explaining the scientific phenomena they experience [12]. Strong teacher knowledge about content will be better equipped to develop conceptual learning instruction [13]. Therefore, the focus of this research is to analyze the difficulties of pre-service chemistry teachers in applying chemical concepts to specific contexts or phenomena, namely ionic fluid (IL) technology.

Ionic liquids (IL) are modern technologies that have many applications in the fields of dissolution, electrolyte materials, and fluid techniques. Ionic liquid material was chosen because it has become an interesting material and raises the curiosity of academics and industry. This new liquid substance has unique properties and offers new phenomenal opportunities for science and technology [6, 14]. The ionic liquid material is chosen because it can act as a means of representation wherein it consists of several entities including objects, phenomena, processes, ideas, and systems [14]. In addition, the context of the material relationship structure with physicochemical properties of ionic liquids has potential in chemistry learning. This is because the application of ionic liquid technology can be used in chemical content as scientific explanations in explaining the relationship between science and technology [6].

An analysis of the difficulties of pre-service chemistry teachers in the context of ionic liquids indicates the need to develop learning designs of relationships between structures and the physicochemical properties of ionic liquids. In addition, the results of this difficulty analysis are used to plan learning designs that will help eliminate previous conceptions and replace them with acceptable scientific views [3]. Therefore, it is important to determine or analyze the difficulties of pre-service chemistry teachers and how they interpret chemical concepts in the context of ionic liquids. Based on this, this study aims to uncover and analyze the difficulties of pre-service chemistry teachers.

2. Methods
This research is the initial stage of some of the stages used in didactic design research. This research was conducted at Sriwijaya University, South Sumatera-Indonesia. The subjects of this study were 23 pre-service chemistry teacher of the 6th semester. This study used a test instrument in the form of an description test consisting of seven parts of questions relating to the relationship of structures with physicochemical properties of ionic liquids and each part was guided by a discourse on ionic liquid technology. The descriptive research method used in this study is presented quantitatively and qualitatively. Quantitative analysis is done by assessing student test results with a scoring system of 1-
100. The scores of each student are categorized into 5 criteria, which are very good, good, sufficient, low and very low [15] as shown in Table 1.

3. Result and Discussion

3.1. Students' difficulties in the context of the relationship of structure to the physicochemical properties of ionic liquids

The essay test consists of 7 parts of the question, namely: (1) Finding chemical content related to the tendency of melting point of molten salt and ionic liquids, (2) The process of ionic formation of NaCl from its elements, (3) Electrostatic force on NaCl compounds (4) Effect of electrostatic force on the movement of ion particles of ionic compounds (molten ionic salts and ionic liquids), (5) the effect of changes in ion size on electrostatic forces and melting point of ionic liquids, (6) Effect of alkyl variation on the melting point of ionic liquids and, (7) Effect of symmetrical structure on the melting point of ionic liquids. The results of the analysis of student answers are shown in table 1.

Table 1. Results of Understanding Student Concepts

| Criteria    | Score  | Number of students | Percentage(%) |
|-------------|--------|--------------------|---------------|
| Very good   | 81-100 | 0                  | 0             |
| Good        | 61-80  | 1                  | 4.3%          |
| Fair        | 41-60  | 6                  | 26.1%         |
| Low         | 21-40  | 14                 | 60.9%         |
| Very low    | 1-20   | 2                  | 8.7%          |

Based on table 1 it was found that 60.9% had a low understanding and 8.7% had a very low understanding. This data shows that students have difficulty in relating the appropriate chemical concepts in explaining a context related to ionic liquid technology. The low and very low accumulated percentage of conceptual understanding of students divided into questions is shown in table 2.

Table 2. Percentage of understanding of the concept of low and very low criteria

| Part of Questions | Number of students | Percentage (%) |
|-------------------|--------------------|----------------|
| 1                 | 20                 | 86.96%         |
| 2                 | 7                  | 30.43%         |
| 3                 | 9                  | 39.13%         |
| 4                 | 15                 | 65.22%         |
| 5                 | 14                 | 60.86%         |
| 6                 | 12                 | 52.17%         |
| 7                 | 20                 | 86.96%         |

Based on table 2, it was found that more than 50% of students had difficulties in sections 1,4,5,6,7. These five sections in detail discuss the relationship of structures to physicochemical properties of ionic liquids. Student difficulties in this section show that students rarely connect the concept of science with technology that is developing at this time so they are difficult to apply the concept of chemistry in the context of ionic liquid technology. Therefore, the difficulties in this section will be discussed in the next sub-topic.

3.2. Students' understanding of the chemical concepts that they will use in explaining the tendency of the melting point of molten salt and ionic liquids
In this section, students mention the chemical concepts that they will use in explaining the tendency of the melting point of molten salt and ionic liquids. Details of the chemical concepts used by pre-service chemistry teachers are shown in Table 3.

Table 3. Details of the chemical concepts used by pre-service chemistry

| Chemical Concepts                                | Number of Students | Percentage |
|--------------------------------------------------|--------------------|------------|
| Chemical Bonding                                 | 3                  | 13%        |
| Colligative Properties of Solution               | 5                  | 22%        |
| Thermochemistry                                  | 1                  | 4%         |
| Salt Hydrolysis                                  | 1                  | 4%         |
| State the names of courses such as Analytical Chemistry, Organic Chemistry, Inorganic Chemistry, Physical Inorganic Chemistry, Physical Chemistry, No Answer or Answer does not contain chemical content | 3                  | 13%        |
|                                                   | 10                 | 44%        |

Based on Table 2 in the first part of the question, 20 students have difficulty in mentioning the exact chemical concepts. Expected keywords such as chemical bonds, ionic bonds, electrostatic forces, lattice energy, cation, and anion types and structural symmetry only appear from three student answers. Some students bring up the topic of the colligative properties and hydrolysis of salt. The emergence of these topics is possible because of the experience of students directly with salt solutions. Students do not understand that salts such as NaCl, NaNO₃, and KNO₃ melt in their pure conditions, not in the form of a solution. Therefore, it can be concluded that students have difficulty in understanding chemical topics at a symbolic and microscopic level. Students find it difficult to associate the tendency to change the melting point of salt with its structure and the interaction of particles inside it microscopically. This is also in accordance with several studies which reveal that melting and dissolution is often confusing process so this confusion can be the result of how students see the melting and dissolving process at the submicroscopic level [7].

3.3. Students' understanding of the influence of the electrostatic force on the movement of ions ionic compound (molten salt ionic and ionic liquids)

In this section, students are asked to analyze, (1) the influence of the strength of the electrostatic force on the movement of ion particles, (2) the effect of ion size on the electrostatic force and the melting point of molten salt and ionic liquid. The questions in this section are guided by Figure 1.

Figure 1. Molten salt structure (left) and Ionic Liquid structure (right) [16]

Based on table 2, part of question 4, 65.22% of students have difficulty analyzing the influence of the strength of the electrostatic force on the movement of ion particles. The results of the analysis of answers show that students find it difficult to explain the movement of ion particles at a symbolic and microscopic level. This is due to their lack of understanding of the nature of particles, namely atoms, molecules and ions and their mental models which are incomplete or incorrect [17,18]. In addition, some
students made the mistake that the influence of the strength of the electrostatic force on the movement of particles in ionic liquids was greater than that of the particles in molten salt. Students do not understand how the interactions between ions that occur are influenced by the strong electrostatic forces acting. The symmetrical form of Na\(^+\) cations and Cl\(^-\) anions makes the bound ions very strong (strong electrostatic force) and the distance between the ions gets closer. Unlike the case with ionic liquids that have large and complex cations so that their interactions with the anion are getting weaker (weak electrostatic forces). This explanation is difficult for students to express. This is due to the fact that most prospective chemistry teachers do not have an adequate understanding of the principles of basic chemistry (instructional). In addition, the causes of difficulties and misunderstandings are also influenced by the teaching of conventional chemistry, which is mostly centered on teachers or educators where students have so far learned through memorization without any emphasis on constructivist approaches [19].

3.4. Students' understanding of the effect of changes in ion size on the electrostatic force and the melting point of ionic liquids.

In this section, students were difficult to analyze the relationship of the structure of ionic compounds (NaCl and 1-ethyl-3-methylimidazolium chloride) to each of their melting points. From the structure provided, students were difficult to analyze the effect of increasing the size of cations on the physical properties of these ionic compounds. This can be seen from the number of students who did not answer questions. Students' difficulties in analyzing a structure make it difficult for them to relate the effect of increasing the size of cations on ionic compounds to melting points and electrostatic forces. This difficulty is seen when students are asked to determine which compound (NaCl or 1-ethyl-3-methylimidazolium chloride) has the greatest electrostatic force. Some students assume that the larger the size of the cation, the greater the electrostatic force. In addition, students also assume that the high and low melting points are not affected by the size of the cation but are only influenced by the atomic number. These things produce a conceptual error. Students do not have enough understanding that the small size of the cation makes the structure symmetrical so that the strength of the electrostatic force that binds the cations and anions is getting bigger. From the results of this analysis, it can be concluded that students lack sufficient basic knowledge and do not precisely analyze the relationship of electrostatic forces with the distance between ions and their influence on the melting point of ionic compounds even though the researcher has given the coulomb force equation in the previous question.

3.5. Students' understanding of the effect of alkyl variations on the melting point of ionic liquids

In this section, the difficulties of students are when (1) analyzing the effect of alkyl variations on the cations of ionic liquid structures on their melting points, (2) concluding the effect of increasing the size of cations and anions on the melting point of ionic liquids. Based on table 2, in part of question 6, 52.17\% of students have low understanding. Students were difficult to analyze the effect of adding alkyl to cations to the melting point of ionic liquids. Students cannot explain that alkyl variations in cations can cause the structure of ionic fluids to become more complex so that interactions with anions are increasingly difficult. In addition, when students were asked to explain the effect of alkyl length variations on cations on melting points based on a graph of prediction and observation of the melting point of 1-alkyl-3-methylimidazolium hexafluorophosphate, students tend to be difficult to represent graphically and explain the interaction of alkyls in cation symbolically and microscopically. In general, students were difficult to explain that the addition of alkyl will affect the complexity of the structure so that the melting point will be lower, but when it reaches the minimum melting point (in hexyl, heptyl or octyl groups), the melting point will begin to increase in line with the length of the group alkyl (large from octyl) in the cation. The increase in the melting point of ionic liquids with alkyl groups greater than octyl will cause van der walls interactions between alkyl molecules bound by cations. This understanding is not yet possessed by students because they are difficult to understand chemistry at a symbolic and microscopic level. In addition, difficulties are also influenced by a lack of understanding
of the chemical concepts of prospective teacher students so that they are difficult to explain the effect of alkyl variations on their melting points.

3.6. Students' understanding of the effect of symmetrical structure on the melting point of ionic liquids
In this section, students have difficulty determining symmetrical and asymmetrical structures. This is due to the lack of understanding of students' concepts of structural geometry. The [Emim]+ cation structure has a complex structure so that the cation shape will affect the charge density which causes the charge to be delocalized. Understanding this concept is not understood by students or does not arise from student answers. Students' difficulties in determining an asymmetrical or symmetrical structure will affect the determination of the melting point of ionic liquids. Thus, the difficulties experienced by these students will affect the determination of ionic liquids that have a lower boiling point if they are faced with different questions later.

4. Conclusion
Based on the results of this study, it can be concluded that 69.6% of pre-service chemistry teachers have low understanding or have difficulty in associating appropriate chemical concepts to explain the context of ionic liquid technology. From the seven part questions given, 86.96% of students had difficulty in mentioning the exact chemical concept related to the difference in melting point of molten salt and ionic liquid. In general, it can be described that pre-service chemistry teachers find it difficult to analyze and explain the effect of cation and anion sizes on the electrostatic force and melting point of ionic liquids. In addition, students also find it difficult to determine structural symmetry and analyze the effect of alkyl variations on cations on the physical properties of ionic liquids. Learning difficulties experienced by pre-service chemistry teachers are influenced by their lack of understanding of the nature of particles, namely atoms, molecules and ions and their incomplete or incorrect mental models. In addition, students' difficulty in answering the questions given is influenced by the lack of a basic understanding of chemical content and is influenced by conventional teaching through memorization without an emphasis on constructivist approaches. So, based on the results of the analysis of the pre-service chemistry teacher's difficulties, the didactic design to be developed must place more emphasis on three levels of chemical representation, namely at the macroscopic, symbolic and submicroscopic levels. In addition, students must also be confronted with phenomena, structures and physical properties, the uniqueness of ionic liquids, experiments and the latest technologies related to ionic liquids so that the didactic design developed can overcome the difficulties experienced by students in understanding the context of the structure's relationship with the physicochemical properties of ionic liquids.

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