Ionic liquids in chemistry education: an experiment IPMC potentially to develop VNOST of pre-service chemistry teachers’

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Abstract. This study aims to introduce IPMC based-ionic liquid as a technology related to school chemistry content and is expected to develop VNOST of pre-service teachers with demonstration method. This demonstration IPMC based on ionic liquid has the potential to introduce four main aspects of VNOST, such as (1) the characteristics of science and technology, (2) the aim of science and scientific research, (3) the characteristics of scientific knowledge and scientific theories, and (4) the relationship between science and technology. The research method used is descriptive qualitative. Like the main purpose of VNOST, the introduction of this IPMC based on ionic liquid is not only introducing technology, but introducing the link between technology and science, especially chemistry content. Context-related chemistry content that is at the stage of making chitosan sulfonate membrane involves chemistry contents in the form of solution ph, Lewis base acid theory, sulfonation reaction, substitution reaction, and conductivity. In addition, the stages of the membrane actuation mechanism involve chemistry contents in the form of electrostatic forces, electrolytes, and the relationship of the melting point with the molecular weight. This research is expected to be developed in order to know that the prototype developed can develop VNOST Pre-service teachers’.

1. Introduction
This evolving technology can be introduced to the world of education through natural science learning that is studied. Therefore, according to Rampal, an understanding of the VNOST (Views Nature of Science and Technology) is very important to be owned by educators because it will affect how educators convey a scientific concept to students. Furthermore it will affect students' motivation and interest in science learning [4]. VNOST is a view of how scientific knowledge is used to explain a phenomenon in technology [1,2].

To understand about the nature of natural science and technology, one must understand 4 main aspects about the relationship between natural science and technology such as (1) characteristics of natural science and technology, (2) purposes of natural science and scientific identification, (3) characteristics of knowledge and scientific theory, and (4) the relationship between natural science and technology [1].

In this research, the selected technology is Ionic Electro Active Polymer (EAPi) using ionic liquid material such as IPMC. IPMC is one type of artificial muscle that which can bend as a result of cations mobility in polymer networks that are given electric current. A relatively low voltage is required to induce bending at IPMC where polymers that have negative ion groups provide channels for positive...
ions mobility [3]. IPMC consists of 2 parts namely actuator and electrolyte. The actuator materials normally such as used in the manufacture of IPMC are ion-exchange polymers, organic polymers that contain ionic groups, but they are covalently bonded. One of the raw materials that can be used and becomes the attention of researchers in developing the IPMC artificial muscle is chitosan [5,6]. These electrolytes are molten salts at room temperature and are environmentally friendly. They are known as ionic liquids [8]. Ionic liquids are known as "green solvents" because they have amazing characteristics such as chemically and thermally stable, low vapour pressure, non-flammability, low volatility and can be recycled [9,10,11]. Ionic liquid used in IPMC applications is cis-oleilimidazolinium iodide.

These contexts about IPMC and ionic liquid are selected because there is a scientific explanation related with natural science and technology that can be used for reinforcing the contents of chemistry learning, developing thinking ability, (process/competency), and they can be used as a discourse for reinforcing the scientific attitudes (attitude toward science) that are demanded in scientific literacy ability. In addition to discussing the context of artificial muscle based ionic liquids, this study also links chemistry content to context. This is because, technology and science especially chemistry cannot be separated in an effort to develop VNOST.

The need for pre-service science teachers who have the right VNOST ability is important. To have a good view of science and technology, science teachers must be given the opportunity to know science and technology from a scientific and technological point of view [13]. One way to look at scientific and technology views is to conduct experiments in the laboratory [14].

Demonstration is one form of experimental activities in the laboratory. Demonstrations in chemistry can be defined as pedagogical activities that aim to illustrate scientific concept [15]. Some studies highlight that good demonstrations can increase understanding, attractiveness, increase their level of motivation and satisfaction. Furthermore, demonstrations can serve as an effective platform to increase students' understanding of certain chemical concepts [15,16].

Based on the description above, this research focuses on introduce technological prototypes, namely IPMC (one type of artificial muscle ionic) based on cis-oleilimidazolinium iodide ionic liquid material which is expected to develop VNOST from pre-service teachers. This context is closely related to the chemical content that schools learn, so it is likely that it can be applied in learning activities by demonstration.

2. Method
This research is the stage in the introduction of technology products, namely kit of experiments prototype IPMC based on ionic liquid with demonstration method. The research method used is descriptive qualitative by describing the relationship between the stages in the demonstration of experiments prototype IPMC based on ionic liquid with chemistry contents and aspects of VNOST. The target in this study is the chemistry pre-service teacher. The instrument developed was data regarding the relationship between experiments prototype IPMC based on ionic liquid with VNOST aspects. This research shows intensively with scientific research and education related to VNOST. Demonstration of experiments prototype IPMC based on ionic liquid consist of making membrane of chitosan sulphonate and IPMC actuation test experiments:

2.1. Making Membrane of Chitosan Sulphonate
The procedure for making sulphonated chitosan membranes is as follows: (1) Chitosan is dissolved in 1% acetic acid and stirred (1.5 gram, 100 mL); (2) printed and dried; (3) the membrane is immersed in 10 mL of 2% sulphuric acid solution for 24 hours (sulphonation process), then washed and dried.

2.2. IPMC Actuation Test Experiments
The sulphonated membrane was cutted, then it was smeared with cis-oleilimidazolinium iodide ionic liquid on both sides. The actuation test was set at 20 Volt to the membrane.
3. Result and Discussion

3.1. The contexts of IPMC and Cis-oleilimidazolinium iodide ionic liquid and their relations with aspects of VNOST

Introduction of technology context, IPMC based-ionic liquid, can develop VNOST. It is because IPMC based-ionic liquid is one of techno science examples. Techno science is one way to combine aspects of science and technology in scientific activities [17]. It supports the construction of knowledge independently and acts as tool, instrument, and device. It emphasizes human active and creative roles in formation of concepts, laws, theories, and it supports teaching solution naturally, which gives weight on personal conception to learn [2].

The views about this VNOST was first developed to pre-service teachers especially to pre-service chemistry teachers through a demonstration from a prototype of IPMC based-ionic liquid because it will affect to how teachers deliver a scientific concept to students, that can lead students' motivation and interest improvement to science learning [1]. The demonstration was selected as one way to introduce IPMC context based-technology because it aims to give learning in real, so the pre-service teachers are expected to be easier to understand the principle of technologies, one of them is IPMC technology [18]. Table 1 presents the relationship between VNOST aspects and the context of IPMC based on ionic liquids.

Table 1. Relationship between IPMC based on ionic liquid experiments and VNOST aspects

| Description of the experiment | VNOST Aspect |
|-------------------------------|--------------|
| The developed IPMC prototype is one of the artificial muscle technologies that is a global issue and the cis-oleilimidazolinium iodide ionic liquid is a material used in technology. IPMC is one type of artificial muscle that is very closely related to science, especially chemistry content. The relationship is in the process of actuation in IPMC based on ionic liquids which can be explained by chemistry content. In the making of artificial muscle, it is used conductive sulphonated chitosan membrane as an artificial muscle until the process of bending test to its membrane. In this process, there are experiment steps i.e. starting from the introduction of materials such as chitosan, NaOH solution, H_2SO_4 solution, CH_3COOH solution, ionic liquid and the introduction of tools such as power supply, set of test equipment, etc. The step of making of conductive sulphonated chitosan through sulphonation reaction process until the bending process occurs on membrane like the working principle of artificial muscle. From this process, the pre-service teachers can know the information about knowledges needed to explain the working principle of artificial muscle can then be associated with chemistry contents for explaining occurred phenomena such as conductive properties of membrane and the occurrence of bending. • When making chitosan sulfonate membranes, the membrane can be conductive because of the ion track in the membrane. This ion track is made with a sulphonation process using sulfuric acid solution. • Then during the actuation testing process, chitosan sulfonate membrane which has been coated with cis-oleilimidazolinium iodide ionic liquid can bend when it is flowed by electricity. The bending process can be explained in chemistry theory. In theory, when electrified the chitosan membrane undergoes bending due to a buildup of ionic cations large in the negative region (presence of electrostatic force), resulting in bending. | Characteristic of science and technology The aim of science and scientific research Characteristic of scientific knowledge and scientific theories Relationship between science and technology |

3.2. The contexts of IPMC and Cis-oleilimidazolinium iodide ionic liquid and their relations with chemistry contents

Like the main principle of VNOST, the demonstration of IPMC based on ionic liquids not only introduces technology, but aims to determine the relationship between technology and science,
especially related chemistry content. Context-related chemical content has been explained in previous exposures intensively with scientific research. In Table 2, a brief description of the relationship between the context of IPMC based on ionic liquids with chemistry content is briefly presented.

Table 2. The link between the stages of the experiment and chemistry content

| The Stages of The Experiment                                      | Related Chemistry Contents                                           |
|-------------------------------------------------------------------|-----------------------------------------------------------------------|
| Making chitosan sulfonate membrane                               | - pH of the solution                                                  |
|                                                                  | - Lewis acid base theory                                              |
|                                                                  | - Sulfonation reaction                                                |
|                                                                  | - Substitution reaction                                               |
|                                                                  | - Conductivity                                                        |
| Actuation of chitosan sulfonate membrane coated with cis-        | - Electrostatic force                                                 |
| oleilimidazolinium iodideionic liquid                            | - Electrolytes                                                        |
|                                                                  | - Relationship between melting point and molecular weight             |

3.2.1. Making Membrane of Chitosan Sulfonate
Chitosan is soluble in dilute acid (polar solvent) with pH < 6.0 because it has amino group with pKa value 6.3 [7]. This is because when chitosan that is in pH m < 6.0, H⁺ ions will be captured by the Free Electron Pair (PEB) of the N atom causing the amino group to be positively charged to form NH₃⁺, so it causes chitosan being cationic and soluble in a polar solvent.

Then, chitosan was processed through a sulphonation process. The sulphonation compound used was sulphuric acid because it is easy to obtain and many other studies use sulphuric acid in the preparation of sulphonated chitosan. The sulphonation process was adapted from the previous research by immersing the chitosan membrane in sulphuric acid for 24 hours at room temperature [19,20]. The optimum concentration of sulphuric acid which can be used for immersion of chitosan membrane is 2%. Theoretically, the sulphonation reactions will occur in some clusters that is free -OH group at C6 atoms and free amine groups at C2 atoms. However, the greater likelihood of sulphonation is in the hydroxy group. This is because in the acidic ambience, the amine group will be protonated [7].

The chitosan membrane has an ion conductivity value of 0 S/cm while the sulphonated chitosan membrane has a conductivity value of 3.8 x 10⁻⁸ to 6.5 x 10⁻⁸ S/cm. This difference in conductivity values is due to the presence of HSO₃⁻ groups in the sulphonated membrane. In the presence of HSO₃⁻ groups on chitosan, it will produce an ion track that will accelerate the motion of the proton (Figure 1). Here is the illustration of how ion trajectory takes place is shown below.

![Figure 1. The ionic track that occurs between the layers of the sulfonate membrane](image)

3.2.2. IPMC Actuation Test Experiments
An assemble from artificial muscles of IPMC was flanking a polyelectrolyte (membranes that were already added an electrolyte) with two electrodes. However, in this research the actuation testing on the artificial muscles of IPMC did not use electrodes, so the sequence was made differently. The sequence that can produce actuation was by coating both sides of the membrane with electrolyte. This electrolyte serves as a cation provider that will cause IPMC to bend and it has function as electron
intermediate from the power supply. Electrolytes that usually used are electrolytes with water solvents, but these electrolytes have some problems, so electrolytes using water as solvent can be replaced with ionic liquids [21,22].

Ionic liquid used in this research is cis-oleilimidazolinium iodide. The cation from this ionic liquid is imidazolinium with R group that sticks on it is a fatty acid (oleic acid). Oleic acid is composed by 18 carbon atoms and 1 double bond (18:1) [23]. The melting point of ionic liquids will decrease as the size of cation increases, but when the minimum value is achieved, the melting point of ionic liquids will start to increase as the molar mass of cation increases [24]. Therefore, cis-oleilimidazolinium iodide has liquid paste form caused by its very high mass molar. Although this ionic liquid has liquid paste form, cations and anions can still move despite their mobility become lower. Ionic liquid crystals also have good ionic conductivity which is about 1.65 x 10⁻³ S/cm.

Based on the results, artificial muscle IPMC can bend at a maximum voltage condition of 20 V with AC current. This is not in accordance with the existing reference that the occurrence of actuation on IPMC requires only a voltage between 1-10 V with AC or DC current [3,4,25]. This is different from some sources because in this research it did not use electrode as electric intermediator (provider of electron), and sulfonated chitosan membrane has very small conductivity properties due to the existence of microscopic pores on the surface. Pore size of chitosan derived from shrimp shell is 64±20 µm [26]. These pores will reduce the ionic conductivity of the membrane due to cut off the ion track on the membrane, so it is possible to use high voltage. The direction of the actuation that occurs is towards to the positive pole, and there are also initially bent toward the negative pole and then move to the positive pole. This is not in accordance with the existing reference that when electricity is applied to the IPMC membrane. The cations inside the membrane move toward electrodes that have different charges with the cations (negatively charged cathodes). The displacement of the cations results, cations buildup at cathode causing swelling and the occurrence of depreciation in the area near the anode (positive electrode). Moreover it will cause actuation or bending on the membrane [3,8,21].

**Figure 2.** Testing of IPMC membrane actuation (left) and before and after the bending mechanism occurring on the IPMC membrane (right)

Figure 2 shows the time before electrified, the cations in the ionic liquids will be close to the anion group on the chitosan membrane (HSO₃⁻) because of the existence of electrostatic force, and the iodide ions will be close to the cis-oleilimidazolinium cation. When the membrane was electrified, the cations on the left side (anode) and on the right side (cathode) will close to the more negative side of the membrane by passing into the membrane pores. On the more negative side there will occur the buildup of cis-oleilimidazolinium cations and will occur the depreciation in the positive electrode area, thus causing bending.

**4. Conclusion**

The demonstration that has been conducted aims to introduce the developing technology that is IPMC based-cis-oleilimidazolinium iodide. This introduction has the potential to develop VNOST of pre-service teachers with introducing 4 main aspects about the relationship between science and technology (VNOST) that relates with the experiment. Furthermore, it has the potential to introduce chemistry contents related with IPMC based cis-oleilimidazolinium iodide such as pH of solution, Lewis acid base theory, sulphonation reaction, substitution reaction, conductivity, electrostatic force,
electrolyte, and the relationship between melting point and molecular weight, so it is possible for the next development by using knowledge obtained through demonstration. The related chemistry concepts are discussed intensively with scientific research that aims to build the bridge between academic and chemistry through the didactic approach to achieve the purpose of science education.

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