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Learning Material of Chemistry in High School Using Multiple Representations

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Abstrak. This paper is intended to develop teaching materials on the material properties of the chemical solution Colligative Secondary Schools and the results of due diligence materials. This research is part of the research and development design to produce teaching materials. Stages of research are conducted, as follows: 1) A preliminary study in the form of analysis and mapping of the content and context; 2) packaging of teaching materials products; 3) validation and trials to determine the feasibility of the product. The teaching materials were developed based on the results of Herron's concept analysis, standard textbook analysis as well as analysis of the material representation of the colligative nature of the solution referring to Gtizkia. Based on the result of the research, it is found that the product of teaching material has characteristic, in which, is connecting the three levels of chemical representation on the colligative nature of the solution using various modes of representation in the form of video, animation, image and text. Macroscopic representations of presentation of experimental phenomena and procedures, submicroscopic representations are visualized using text, images and video / animation inserts that relate them to symbolic representations. The teaching materials are also equipped with examples of problems and exercises that connect three levels of representation. The results of validation and feasibility analysis show that the product of teaching materials is valid and feasible to be used as a learning resource in High School

1. Introduction

The colligative nature of the solution is one of the chemicals that was taught in the Secondary School of Class XII. Student's understanding of the solution colligative properties materials is demonstrated by its ability to connect macroscopic, submicroscopic and symbolic levels in the context of problem solving [1]. However, there is a tendency of teachers to emphasize the symbolic representation of algorithmic calculations [2]. Generally, teachers also do not have the right way of experience to visualize submicroscopic level [3]. This resulted in students tended to experience misconceptions, both contextually and conceptually [4].

Teaching materials in the form of textbooks tend to be the main guidance for teachers and students of the School [5]. This very important role has not been supported by the provision of adequate teaching materials in accordance with the characteristics of chemistry. Analysis of Chemistry textbooks used in High School [6], [7]: shows the tendency of presentation of content using deductive flow, macro phenomena not associated with sub micro level and visualization of the concept through images do not present the exact chemical correlation. Multiple representation is very important as a reference for developing teaching materials, because of the characteristics of chemical concepts require external representation through various modes, among others: the modes of descriptive representation (verbal, graphs, tables), experimental, mathematical, figurative (pictorial, analogies and metaphors) And visual [8].

In this paper, the material content analysis of Solution Colligative Properties uses multiple chemical representations aimed at developing secondary school chemistry materials and the feasibility test results of teaching materials.

2. Methods

This research is part of the research and development design (modification of [9]) to produce teaching materials. Stages of research conducted, as follows: 1) Preliminary study in the form of analysis and mapping of content and context; 2) packaging of teaching materials products; 3) validation and trials to determine the feasibility of the product. The teaching material was developed based on the results of concept analysis based on Herron [10], the analysis of standard textbooks [11] and [12] as well as analysis of the material representation of the colligative nature of the solution which refers to Gtizkia [13]

Validation of teaching materials was done to five validators consisting of two lecturers of chemistry education, one multimedia expert and two chemistry teachers of Senior High School. The product was tested limited to 17 high school students of XII class to get response about the ease and usefulness of the product.

3. Results and discussion

The colligative nature of the solution includes a concept-based type of principle. The materials of the colligative properties of the solution include the colligative properties of the non-electrolyte and electrolyte solutions, each having a sub-concept of decreasing vapor pressure, boiling point rise, decreasing freezing point and osmotic pressure.

The colligative nature of a solution depends only on the ratio of the number of solute particles and the number of particles in a system. From a thermodynamic perspective, the colligative nature of the solution can be explained by recognizing the formation of the solution resulting in increased entropy system, resulting in a decrease in Gibbs free energy. The presence of a solute (non-volatile) increases the thermodynamic stability, so it takes a higher temperature to change the solution from liquid into a gas (vapor). Instead it takes a lower temperature to freeze it. While osmosis is seen as a spontaneous process, because the flow of water into the solution results in a decrease in free energy from the system. The explanation based on the thermodynamic perspective relates to the macroscopic characteristics of the system. In High School, such explanations are not used because the basic concepts of thermodynamics are not specifically learned. Therefore, it is simple to use an explanation that refers to the perspective of molecular kinetics [14] using the appropriate modes of representation.

To deliver on the difference of the pure solvent-solvent nature with the solution, the phenomenon of the evaporation process occurs in freshwater aquariums and aquariums. This phenomenon is a macroscopic representation that students can observe by themselves.
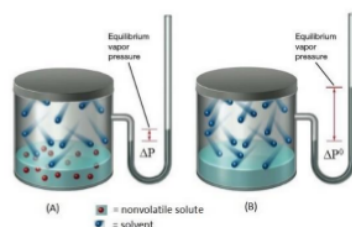
**Figure 1.** Measurements: (A) the vapour pressure of the solution with (B) and the pure solvent

The phenomenon, then, is related to the description of the submicroscopic level in the form of the solvent molecular movement, from the liquid phase to the gas phase and the effect of the solute on the vapor pressure of the solution (Fig. 1). Figure 1 includes three modified representation levels of

[11]. The representation in the teaching materials is presented in the form of pictures and animations. The text is given in the form of a referring question and an explanation intended for students to analyze the effect of the solute on the reduction of the vapor pressure of the solution conceptually. Furthermore, given the problem of calculations that apply Raoult's Law to the calculation of the reduced vapor pressure of the solution (ΔP):

$$\Delta P = X_{solute} \cdot P^0{}_{solvent}$$

X_{solute} = Mole fraction of the solute and $P^0{}_{solvent}$ = solvent vapor pressure

Although Raoult's Law is for ideal solutions, this approach is also used for real solutions. The deviation significantly increases with the added concentration of solute. Therefore Raoult's law works well, when the concentration of low solute and intermolecular forces between the solute and solvent particles is almost the same[15].
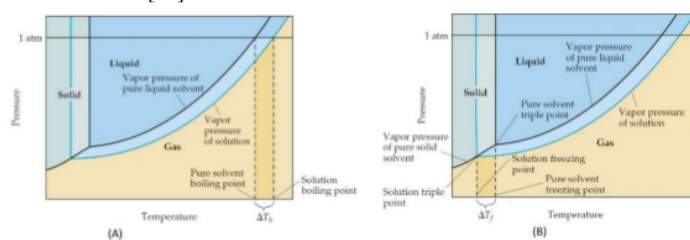
Figure 2. Diagram P-T relationship with the vapor pressure (A) solution boiling point rise (ΔT_b) and (B) the freezing point depression (ΔT_f) [12]

If the solute is an electrolyte, the colligative nature of the solution is determined by the amount of solute ions. The electrolyte ions are more numerous than the number of non-electrolyte molecules at the same concentration. The presence of dissolved ions in the solution is expressed by van't Hoff (i) factor.

The sub-concept of vapor pressure decrease becomes the determinant for understanding the sub-concept of boiling point rise and the decrease in freezing point. Connectedness between the vapor pressure drop (ΔP) boiling point elevation (ΔT_b) and the solution freezing point depression (ΔT_f) depicted in diagrammatic form PT (Figure 2). The diagram in Figure 2 is modified in the form of animation and presented gradually with the referring questions, so that students observe more closely the connectedness of each variable presented, as suggested by Fong [15].

At sub concepts of the boiling point elevation (ΔT_b) the representation given macroscopic phenomenon that compares the boiling point of pure water and boiling sugar solution. In the teaching materials, the phenomenon is equipped with an animation of the working process of measuring the pure solvent boiling point and solution. The boiling point of the solution (non-volatile solute) is higher than that of the pure solvent. This is due to the interaction between the solute molecules and the solvent, so that the temperature required to reach the boiling point becomes higher (figure 3).

Figure 3. The submicroscopic representation of comparative evaporation processes; (A) pure solvent and (B) Solution

Level of macroscopic freezing point depression (ΔT_f) represented by the phenomenon of cooling on the mixture in ice cream made by mixing salt and pieces of ice. Salt serves to reduce the freezing point of the solution so ice cream can last long. In the teaching materials, the phenomenon is equipped with an animation of the working process of measuring the pure solvent boiling point and solution. The phenomenon is visualized by submicroscopic representation of images and text showing the effect of solute on the decrease of freezing point of solution. Both representations are then associated with symbolic representations.

For the sub-concept of osmotic pressure (π), the macroscopic level is represented by the osmotic phenomenon of the cucumber that wilted after a week soaked in saline solution, dialysis method and seawater treatment (reverse osmosis).
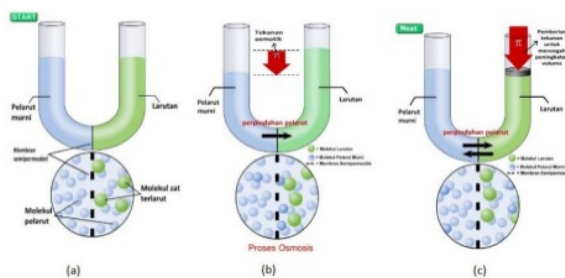
Figure 4. Screenshot of animated osmosis and reverse osmosis processes

The representational modes used in this concept are images, animations (videos), calculation formulas, and text explaining the interrelationship between the macroscopic, submicroscopic and symbolic levels. Each is visualized with a submicroscopic representation of images, descriptions and animations (video). Figure 6 shows an animated screenshot that represents the macro and submicroscopic levels of the osmosis and reverse osmosis processes.

Based on the explanation above, each sub concepts in teaching materials just begins with presenting the phenomenon in daily life, which is then connected to the macroscopic representation of submicroscopic and symbolic representations. It is intended that the instructional design involves the correlation of chemical representations between macroscopic, submicroscopic and symbolic levels using representational modes such as pictures, videos, descriptions and experiments, to satisfy multiple representation criteria as Farida et al. [1]. The inductive plot is used so that students are able to interpret phenomena and data, analyze and draw conclusions. It is expected that students can construct knowledge [16] and be able to transfer their knowledge to solve problems [4].

Next is packaging materials in the form of printed books that are equipped with a *compact disc* (CD) to present the animation/video. Validation of teaching materials was done to five chemistry

experts. Validation is done by filling the validation sheet in the form of spread sheets and the questionnaire. Aspects that become assessments on teaching materials include aspects of material clarity, aspects of supporting elements and aspects of the display. In general, the improvement of expert advice on teaching materials that is the molecule of sugar solution must be clear, solving one example problem, and mistakes in writing some words in teaching materials. Furthermore, a limited trial was conducted on 17 high school students who had previously studied the colligative nature of the solution using other teaching materials. Students were asked their response by using a questionnaire after they studied the content of teaching materials of the colligative nature of the solution. In table 1 presented student responses to teaching materials research products

Table 1. Students response to the teaching materials

No		Resume Questions	% Students Response n=17		
			Good	Enough	Less
1	a)	The relevance of matter with contextual phenomena	100	-	-
2	b)	Easy to understand the material	82,4	17,6	-
	c)	Ease of understanding of macroscopic aspects	94,1	5,9	-
	d)	Ease of understanding of sub macroscopic aspects	70,6	23,5	5,9
	e)	Ease in understanding the symbolic aspects of the material's colligative nature of the solution	82,4	17,6	-
	f)	Easy in connecting the three levels of representation	82,4	11,7	5,9
3	g)	Raises motivation to learn content	76,5	23,5	-
	h)	Cause curiosity to learn the content	64,7	29,4	5,9
	i)	The trial procedure is easy to do	82,4	5,9	11,7
		Average	81,7	15,0	3,3

From table 1 it can be seen that some students respond well to the teaching materials of the colligative nature of the solution.

4. Conclusion
Based on the result of the research, it is found a teaching material product that has characteristic, connecting three levels of chemical representation on colligative properties of solution using various mode of representation in the form of video, animation, image and text. Macroscopic representations of presentation of experimental phenomena and procedures, submicroscopic representations are visualized using text, images and video/animation inserts that relate them to symbolic representations. The teaching materials are also equipped with examples of problems and exercises that connect three levels of representation. The results of validation and feasibility analysis show that the product of teaching materials is valid and feasible to be used as a learning resource in High School.

Acknowledgments

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