How to develop SETS-based colloidal system teaching materials?

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Abstract. This study aims to develop SETS-based colloidal system teaching materials through 4S TMD method to develop students’ creativity. Research method in this study was Richey’s and Klein’s development research consisting of design, development, and evaluation. This study was conducted until the step of design and development. The procedure used in the development step was the 4S TMD method at the selection and structuring steps. The selection step consisted of curriculum analysis, indicators development, international textbooks analysis, and identification of values or aspects of SETS integrated into the teaching materials of the colloidal system. The structuring step had been developed concept maps, macro-structures, and multiple representations. The results of the selection and structuring steps had been reviewed and validated by expert lecturers in chemistry education. The results showed that the teaching materials developed were in accordance with the curriculum, scientifically correct, there were skills developed, and the SETS aspects was in accordance with the phenomenon presented.

1. Introduction
Teaching materials are part of the curriculum, and frequently become the reference for the teachers and the students [1]. A good teaching material must be in accordance with the learning objectives, the material contained therein must be scientifically correct, and the explanation should be suitable to the level of cognitive development of the students who will use it [2].

The current teaching materials are not yet fully in accordance with the curriculum demands and there are still those that are not in accordance with the scientific rules. Husna [3] revealed that the breadth and depth of material and topics that build the materials outweighs what the curriculum demands, so a great deal of materials that should be given at the college level, were already given in school. Research conducted by Majid [4] on the senior high school chemistry textbooks of colloidal system (author R publisher of Q) that mostly used in SMA Negeri in Bandung City not yet in accordance with the demand of curriculum, not all concepts on colloidal system material is scientifically correct, and no value embedded in the material of colloidal system in the textbook.

Several errors were found in presenting the material in a high school chemistry book on colloidal system material that may cause students’ misconceptions and misunderstanding. Misconceptions are at risk of resistance that may disrupt further learning [5]. Afriansi & Nasrudin [6] stated that students were experiencing misconceptions at the sub-microscopic level of the colloidal concept, such as the movement of atoms or ions of a colloid that shows colloidal properties. Research conducted by Wulandari, et al. [7] also mentioned that students experienced misconceptions on the concepts of microscopic particles, precipitates on suspensions, dispersed particles or solvents, Tyndall effects,
Brownian motion, and concepts not yet understood by students are the size of colloidal particles, solutions, and suspensions.

The colloidal system material is actually contextual [8], where it greatly emphasizes the application of colloids in everyday life. It was reflected on the basic competence of colloid material in the curriculum 2013. Application of colloidal principles in everyday life can be found on the field of health technology such as hemodialysis, prevention of industrial smoke pollution to the environment such as using precipitator cottrell, provision of water supply for the community, food industry, medicine, cosmetics, and others. To this point, apparently there is a linkage between colloidal matter and one of the contextual approaches, i.e. SETS (Science, Environment, Technology, and Society). In this approach, the students learn not only the concepts of science, but also are introduced to aspects of technology, and the role of technology in society and the environment [9]. Yoruk et al [10] stated that the lessons based on the SETS approach had a positive effect on the correlation between students and the real world.

Majid [4] stated that no value was found in the material of the colloidal system in the high school chemistry book (author R publisher Q), that mostly used in SMA Negeri in Bandung. Whereas in the curriculum of 2013, specifically the basic competence on the material colloid system requires learners to be able to make food or other products in form of colloid or involving the principle of colloids. The basic competence is an effort to encourage students’ creativity whose importance was emphasized in the National Education System Law no. 20 of 2003 which stated that education is expected to develop the learners’ potential to be human beings who are cautious, noble, capable, creative, and independent as well.

There are several methods to develop teaching materials, including ADDIE, 4-D, ASSURE and 4S TMD [11]. In the early steps of each of these development methods, needs analysis and planning of teaching materials to be developed were equally conducted. Next is the development step of teaching materials. At the development step, the ADDIE, 4-D and ASSURE methods do not explain in detail how to create the instructional material to be developed. While the 4S TMD method explains in detail how to develop the teaching materials starting with the step of selection, structuring, characterization, and didactic reduction. After the material is finished, the next step is to do a test and followed by a revision. In the ADDIE, 4-D and ASSURE methods are not described in detail the way in which to revise the teaching materials. While the 4S TMD method explains in detail how to revise the teaching materials through the didactic reduction step. So this research aims to develop SETS-based colloidal system teaching materials through 4S TMD method to develop students’ creativity.

2. Method

The research method used was first type of Development Research, namely design, development, and evaluation of a product [12]. The design phase began by analyzing the problems and misconceptions of high school chemistry books and the study of literature on development of teaching materials. At the development step, the procedures used in the development of teaching materials using Four Step Teaching Material Development (4S TMD) method in the selection and structuring steps. The subjects of this research were SETS-based colloidal system teaching materials. Data were collected through reviews at the selection and structuring steps, then the data is analysed. The results of the selection and structuring steps are reviewed by content experts and pedagogical experts in chemistry education.

3. Results and Discussion

3.1. Selection step

The concept selection step included the development of indicators, material selection, values selection and related SETS. Indicator development begins with analyzing the curriculum. The curriculum analysis began with the selection of Basic Competencies (KD). On the topic of the colloidal system, there were two KDs given by National Education Department (Depdiknas), i.e. KD 3.15 classifies various types of colloidal systems and explains the use of colloids in life by their properties, and KD 4.15 creating food or other products that are colloid or involve colloidal principles.

KD 3.15 was developed into seven indicators and KD 4.15 was developed into two indicators, because KD. 4.15 is practicum or experimental so it is more appropriate for learning activities. The next
step was to identify the concept label in accordance with the indicators developed. The results of the formulation of indicators and the identification of concept labels can be seen in Table 1.

| Table 1. Indicators and concept labels KD.3.15 in colloidal system material |
|--------------------------|--------------------------|--------------------------|
| KD                      | Indicators               | Concept labels            |
| 3.15                    | Analyzing the role of colloids in real life by its properties. | Solution; Suspension; Colloid; Foam; Solid foam; Aerosol; Solid aerosols; Emulsion; Solid emulsion; Sol; Solid sol; Tyndall effect; Brownian motion; Adsorption; Electrophoresis; Coagulation; Protective colloids; Dialysis; Lyophobic colloids; Lyophilic colloids; Condensation; Dispersion; Delta formation; Industrial smoke filtering; Hemodialysis; and water purification. |
| 1.                      | Distinguishing colloids, suspensions, and solutions.          |                              |
| 2.                      | Explaining the definition of colloids.                      |                              |
| 3.                      | Grouping colloids based on the dispersing medium and dispersed phase. |                              |
| 4.                      | Explaining the properties of colloids.                      |                              |
| 5.                      | Explaining the lyophobic and lyophilic colloids.           |                              |
| 6.                      | Explaining the process of colloid making.                   |                              |
| 7.                      | Analyzing the application of colloids in everyday life.     |                              |

Table 1 shows indicators and concept labels had been reviewed and validated by expert lecturers in the chemistry education. The review was conducted to observe the appropriateness of indicators and concept labels with curriculum demands. The next step was to look for the conceptual descriptions of internationally recognized textbooks to verify the materials’ accuracy. This is in accordance with one of the objectives of the selection step of the instructional materials, which is the materials are scientifically correct [11]. The textbook used as a reference at this step of selection are 30 books, among others are University Chemistry by Bailar, J. C., Moeller, T., & Kleinberg, J., Principles Of General Chemistry by Burman, H. G., Fundamentals Of Physical Chemistry by Crockford, H. D., & Knight, S. B., College Chemistry Third Edition by Frey, P. R., The Elements of Physical Chemistry by Goddard, F. W., & James, E. J., Fundamentals of General, Organic, and Biological Chemistry by Holum, J. R., College Chemistry Fourth Edition by King, G. B., & Caldwell, W. E., Practical Physical Chemistry Ninth Edition by Levitt, B. P., Chemistry In Context: Applying Chemistry To Society, Eighth Edition by Middlecamp, C. H., Mury, M. T., Anderson, K. L., Bentley, A. K., Cann, M. C., Ellis, J. P., et al., Chemistry by Perros, T. P., The Chemistry of Matter by Pierce, J. B., The Nature Of Atoms And Molecules: A General Chemistry by Scott, E. C., & Kanda, F. A., Chemistry by Sienko, M. J., & Plane, R. A., Chemistry Structure and Dynamics Fifth Edition by Spencer, J. N., Bodner, G. M., & Rickard, L. H., and Experiment in Physical Chemistry by Steinbach, O. F., & King, C. V.

The next step is to develop the values, skills, and aspects of SETS that can be integrated into the teaching materials of the colloidal system. Based on the results of the analysis of these values, there were six related values consisting of religious, creative, reading, environmental awareness, social awareness, and appreciation of the achievements or performance of others. The values and aspects of the developed SETS were evaluated and reviewed by expert lecturers in chemistry education. This review step was conducted to see the consistency of value or aspects of SETS with the material description. The relevance of the material to the SETS aspect showed that the material presented to the students through the teaching materials developed not only contained chemistry materials but also has a close connection with their daily life. This was in line with the other objectives of the selection step, i.e. the instructional materials are beneficial for the students [11].

3.2. Structuring step
The structuring step through organizing concepts and materials into concept maps, macro-structures, and multiple representations. Figure 1 show resulting concept map.
Figure 1 shows concept maps colloid system, creating a concept maps aims to help students not to learn partially as well as to know the position of the concept on the building structure of learning materials [11]. Concept maps developed was reviewed by expert lecturers to see accuracy hierarchy of concept maps and concept maps resulted. The next step on structuring is create of macro-structures. Macro-structures serves to maintain the accuracy and clarity of correlation among texts to facilitate the writing of teaching materials [11]. The macro-structures that has been prepared had been through the review step and the suggestion by expert lecturers to obtain macro structure, shown in figure 2.

Figure 2 showed macro-structures of colloidal system. The materials were mapped in a two-dimensional model, namely the dimensions of progression and elaboration. The dimension of progression or vertical dimension in the form of a downward plot indicated macro precision, whereas the elaboration or horizontal dimensions to the right were a means of achieving clarity or explanation criteria of a subject matter [11]. The next step in the structuring step was the multiple representation analysis on the developed concept. Multiple representations are the presentation of chemical concepts in teaching materials consisting of macroscopic, submicroscopic, and symbolic [13] [14] [15]. The presentation of the macroscopic level on the colloidal concept was based on the SETS aspects. Table 2 showed multiple representations in one of the concepts of a colloidal system.


### Table 2. Multiple representations in colloidal system

<table>
<thead>
<tr>
<th>Concept</th>
<th>Macroscopic</th>
<th>Submicroscopic</th>
<th>Symbolic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tyndall effect</td>
<td>Light scattering by colloidal particles is called the Tyndall Effect. Source: (Rittner &amp; Bailey, 2005, p. 270)</td>
<td>The size of colloidal particles is relatively large compared to the solution so that it can reflect light that falls on it. When light is passed into the colloidal system the light will be reflected by colloidal particles in all directions so as to appear as light scattering. The phenomenon of Tyndall's effect on the light beam passing through the trees is produced by the reflection of the light rays from each colloid particles or dust particles. Source: (Frey, 1965, p. 557)</td>
<td>Image of Tyndall effect model Source: (<a href="http://google.com">http://google.com</a>)</td>
</tr>
<tr>
<td></td>
<td><a href="http://google.com">Image of light beam in the forest</a></td>
<td><a href="http://google.com">Particles found in solution</a></td>
<td><a href="http://google.com">Image of Tyndall effect model</a></td>
</tr>
</tbody>
</table>

Table 2 shows multiple representation on colloidal system. The macroscopic level was based on the phenomena occurring in everyday life based on the SETS aspects (the approach used in teaching materials development). The results of multiple representations were then compiled into a draft of the first teaching materials adapted to concept maps and macro structures. The draft of this teaching materials had been through the step of review and validation by expert lecturers in chemistry education. Review results indicated that multiple representations presented on teaching materials have been in accordance with SETS aspects.

### 4. Conclusion

In this study, SETS-based teaching materials had been developed on the topic of colloidal system through 4S TMD method to develop students' creativity. The results of the review indicated that the developed material has been consistent with the curriculum, scientifically correct, there are skills developed, and the SETS aspect was consistent with the phenomenon or material presented. The result of these steps of selection and structuring was the draft of SETS-based teaching materials.

### 5. References


