How to develop SETS-based electronic book to improve student’s science literacy with 4S TMD models?

O Lestar1,*, S Anwar1, G Priscylio3, W S Wahyun1, C Oktasari1 and N R Agustin1

1 Departemen Pendidikan Kimia, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia
2 Departemen Pendidikan IPA, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia

*oktrilestari1994@upi.edu

Abstract. This study aims to develop teaching materials on the rate of reaction based on Science, Environment, Technology and society (SETS) to improve students’ scientific literacy. The research method used is Developmental Research (DR) with Four Steps Teaching Material Development (4S-TMD) models. This article is the first part of the development of teaching material which includes selection and structuring steps. In the selection stage, the development of indicators that are in accordance with the demands of the curriculum, explains the concept of reaction rate using standardized textbook sources, and analyzes SETS which can be related to the concept of reaction rates. In the structuring stage consist of concept maps, macro structures and multiple representations are developed that connect between representations of macroscopic, sub microscopic and symbolic levels. The results of the selection and structuring steps are evaluated by expert lecturers. The results show that the teaching materials developed are in accordance with the demands of the curriculum, scientific certainty has been ensured and the phenomena presented are in accordance with the aspect of SETS and concept maps, macro structures and multiple representations developed are valid. The first part of the development of teaching materials which includes the selection and structuring steps resulted in a draft of SETS-based reaction rate teaching materials. Next step, we will doing characterization and didactic reduction stage to draft teaching material.

1. Introduction

Good chemistry learning is learning chemistry that can give meaning to students. In chemistry learning has a goal so that students can master the concepts, be scientific and be able to understand the concepts of chemistry that ultimately can solve the problems that are in it. This can be seen from the learning process the teacher can associate material with everyday life. However, most students have difficulty in relating the knowledge of chemistry they learn in school to the natural phenomena they encounter in everyday life [1-3]. Learning chemistry at school today often does not associate concepts taught with natural phenomena in life. Therefore, it is necessary to have an approach applied in chemistry learning that can support the realization of meaningful learning, one of which is the Science, Environment, Technology and Society (SETS) approach. In order for learning to take place effectively, a support is needed, namely teaching material. Teaching materials are a set of learning tools or tools that contain learning material that is designed systematically and interestingly in order to achieve the expected goals,
namely achieving learning competencies. Through good teaching materials, students can master competencies according to the speed of learning they have and with good teaching materials too, educators can explore the impact of argumentation on students' conceptual understanding [4-7].

Progress in computer-based education is seen as an effective way to improve the learning process by providing assistance and compensation for students with special needs [8-11]. Developing e-books can help students access learning and other curriculum support materials to obtain sources of information and knowledge for mastering literacy [12-16] one of the potential advantages of the e-book is that it can direct students to improve the student's literacy skills [17-19]. The e-book was developed with the 4S TMD development method (Four Steps Teaching Material Development). The method for developing the Four Steps Teaching Material Development (4S TMD) consists of four stages, namely Selection, Structuring, Characterization, and Didactic Reduction [20]. The advantages of Four Step Teaching Materials Development (4S TMD) not only select subject matter from sources of teaching materials such as textbooks or other reference books, but also develop values that can be explored by students when studying the subject matter. Stages 4S TMD did not stop at the selection process, but there were three other stages used to develop teaching materials. The three stages are each stage of structuring, the stages of characterization and stages of reduction that are not found in how to process other teaching materials. These three stages are the advanced stages that must be done in order to obtain teaching materials that are appropriate to the students' needs and the stages of students' cognitive development. In these three advanced stages, involving students to construct the structure of concepts in the minds of students from multiple representations of concepts, characterizing material concepts based on the level of difficulty according to students, and reducing the level of difficulty so that students can better understand the concept of material presented in teaching materials, so it is important to develop teaching materials based on philosophical, psychological, and didactic methods with the Four Steps Teaching Material Development (4S TMD) method. But in this article, we discuss the results of the study until the stages of structuring, while the stages of characterization and reduction in the research didactic are still ongoing. The e-book was developed using the 4S TMD development method based on the SETS approach, because the SETS approach is an approach that contains the concepts of science, technology, and society. Approaches that cover the concepts of science, technology, and society are interesting aspects of science education reform, which offer answers to problems in science education [21,22].

SETS problems began as a matter of science, technology and society; that is, they are rooted in the interactions of these three problems, and "later evolved to include the environment". SETS education must approach the impact of science on society and the environment. SETS is convincing in science and technology [23,24]. Teaching materials made using the SETS approach can help students to improve students' scientific literacy because the presentation of the material is arranged based on daily life that covers aspects of science, environment, technology and society so that students' scientific literacy increases with their knowledge [25,26]. Science literacy is also measured from the perspective of scientific knowledge, the importance of using knowledge in making decisions and beliefs that students must build their own scientific understanding through making and doing and discovering real life [27-29]. In this study, the chemical material that will be developed in the form of an e-book is the reaction rate material. The rate of reaction is one of the chemical materials which is a component of the curriculum that can promote students' intellectual development which includes fundamental topics in chemistry involving particles, size, temperature, and the presence of catalysts introduced as factors that can influence how quickly forming solutions or metal objects corrode, for example [30-32]. Development in chemistry learning is how students learn concepts, practices, and ways of thinking in chemistry, uncover challenges in learning difficulties, and develop effective teaching approaches to overcome the difficulties revealed in accordance with the goals of chemical education [33]. Therefore, it is expected that the development of the SETS-based e-book on reaction rate material using the 4S TMD development model can improve students' scientific literacy because the presentation of material is arranged based on daily life and developed teaching materials can bring students closer to their lives so students can solve problems that arise in their daily lives. The results of the translation of this paper are some of the theses that are being carried out.
This study aims to develop teaching materials on reaction rate material with the SETS approach that uses the Four Steps Material Teaching Development (4S TMD) method which consists of four steps: selection, structuring, characterization, and didactic reduction.

2. Method
The research method used is developmental research proposed by Richey and Klein. The procedure of this study consists of three stages, namely design, develop and evaluate[34]. The design phase begins with a study of the teaching materials used today and it is found that the teaching materials used today are not fully in accordance with the demands of the curriculum and are not fully in accordance with scientific rules, especially the chemical teaching materials in the reaction rate material.

At the develop stage, the 4S TMD method is used to develop teaching materials. The 4S TMD method consists of four steps, namely selection, structuring, characterization and reduction didactic[20]. This article is the first part of developing teaching materials which includes selection and structuring steps. At the selection stage, it starts with developing a reaction rate indicator in accordance with the demands of the curriculum, then develops the concept of reaction rates with standardized textbook sources, and then analyzes SETS which can be integrated in the concept of reaction rates. In the structuring stage, concept maps, macro structures and multiple representations are developed that connect between representations of macroscopic, submicroscopic and symbolic levels. The results of the selection and structuring stages are evaluated by expert lecturers. In this article, we explain the results of the study to the structuring step, then later on the didactic characterization and reduction steps are still on going.
Figure 1. The teaching materials development flow uses the 4S TMD method with SETS (Science, Environment, Technology, and Society) values integrated in the DR (Developmental Research) procedure.

3. Results and discussion

3.1. Characteristics of teaching materials
Teaching materials developed in this study are teaching materials in the form of e-books on SETS-based teaching materials using steps to develop TMD 4S teaching materials. The four stages consist of the stages of selection, structuring, characterization, and didactic reduction. Each stage has gone through
the review and evaluation phase, but in this study only carried out until the structuring stage.

### 3.1.1. Selection step

The selection phase consists of three parts. The first part is developing indicators in accordance with the demands of the curriculum. The most important aspect in designing the development of teaching materials is paying attention to the demands of the curriculum, meaning teaching materials must be prepared in accordance with the applicable curriculum [35]. Teaching materials developed are about the rate of reaction is KD 3.7, KD 4.7 and KD 3.6. In KD 3.7 and KD 3.6 contains the concept of reaction rate and KD 4.7 are practical. The second part is identifying label concepts that are in accordance with the indicators developed. Development of indicators and identification of label concepts can be seen in Table 1.

| KD | Indicator | Concept Label |
|----|-----------|--------------|
| 3.7 Determine the reaction order and reaction rate constant based on Experimental data | 1. Explain the rate of reaction | Reaction rate |
| | 2. Understand the reaction rate equation | Equation of the reaction rate |
| | 3. Explain the law of the rate of reaction | Law of the rate of reaction |
| | 4. Understand reaction order | Reaction order |
| | 5. Explain reaction rate constant | Reaction rate constant |
| | 6. Determine the reaction rate | Determination of the reaction rate |
| | 7. Determine reaction order and rate constant based on experimental data. | Determination of reaction order and rate constant |
| | 8. Understand reaction rates in graphical form | Graph of reaction rates |

Table 1 shows that there are 8 indicators developed in the reaction rate material. The indicators developed are evaluated by reviewing by expert lecturers. Review is conducted to see the suitability of indicators with basic competencies. Determination of label concepts is done to determine the core concepts of the reaction rate material. After labeling the concept is determined, followed by looking for explanations of concepts from standardized textbooks. To guarantee the scientific correctness of each concept, the explanation of the concept is taken from standardized textbooks which have been recognized by the scientists. In this study the source material in the form of basic chemistry books and international textbooks. Books that used as a reference are:

| No. | Author | Year | Book Title |
|-----|--------|------|------------|
| 1.  | Whitten, K.W., Davis R.E., and Peck L | 2008 | General Chemistry Seventh Edition |
| 2.  | McMurry, J. and R.C. Fay | 2004 | Chemistry Fourth Edition |
| 3.  | Chang, Raymond and Overby, Jason | 2005 | Chemistry Tenth Edition |
| 4.  | Silberberg, Martin S | 2010 | Principles of General Chemistry |
| 5.  | Brady, James, Jespersen, Neil and Hyslop, Alison | 2015 | Chemistry The Molecular Nature of Matter |

The next step is the development of values or skills that can be developed through material reaction rates such as religious values, social care, tolerance, creativity, environmental care and discipline. Table 3 shows an example of the relevance of values to concepts.
Table 3. Value linkage with rate reaction concept.

| No | Concept description | Related value | Value linkage with concept |
|----|---------------------|---------------|---------------------------|
| 1  | The reaction rate is a change in the concentration of reactants or products with time (M/s). We can observe the course of the reaction by monitoring the decreasing concentration of reactants or increasing the concentration of the product. Rate is expressed in changes in concentration with time. A→B | Science Environmental | Pay attention to the iron ties that are around us. Iron bonding reactions: certain parts of iron act as anodes, where iron undergoes oxidation. |

So, the reaction above can be stated as follows:

$$\text{Rate} = \frac{\Delta[A]}{\Delta t} \quad \text{or} \quad \text{Rate} = \frac{\Delta[B]}{\Delta t}$$

**Figure 2. Ironworks.**

Fe(s) → Fe^{2+}(aq) + 2e^-

The released electrons in the anode flow to another part of the iron which acts as a cathode, where oxygen is reduced.

O_2(g) + 4H^+(aq) + 4e^- → 2H_2O(l)

and try to see fireworks when burned will react very quickly with fire, with its chemical reaction

KClO_3 + S + H_2O -> KCl + SO_2 + H_2O

**Figure 3. Fireworks**
Table 3. Cont.

2 Effect of surface area on reaction rates. Molecules must mix to collide. The frequency of collisions between molecules also depends on the physical state of the reactants. When reactants are in the same phase, as in aqueous solution, random thermal movements bring them into contact. When they are in a different phase, contact only occurs at the interface, so strong stirring and grinding may be needed. The larger the solid or liquid reactant, the greater the surface area per unit volume, the more contact that occurs with other reactants, and the faster the reaction occurs.

The value of science and environment is contained in this material because this material explains the examples that exist in everyday life in the environment that we often encounter easily and can also know the science of chemical reactions to the material of the reaction rate. By learning it, we realize that what is around us has chemical reactions that can react quickly and slowly. In addition to iron and fireworks, look for other examples of reaction rates.

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The value of technology and society is found in this material, for example in the ceramics industry, materials in making ceramics need to be refined to a certain size, called mesh. Material size or surface area plays an important role in the ceramic industry. If the surface area of the touch is made of small ceramic material or the grain is rough, cavities will occur which will cause the ceramics to crack and shrink. Surface area also plays an important role in making cement. If the cement material becomes smoother, the contact surface area gets bigger and the results become dense and compact so that the building becomes strong.

Figure 4. Ceramics

The positive impact of the ceramics industry on the community is in the construction of houses, especially making the floor of the house.
Table 3 shows the value of science and environment in the concept of the reaction rate based on the speed of the reaction. This teaching material is made oriented to SETS. Where SETS is a way of thinking that everything faced by humans in this life contains aspects of science, environment, technology and society that affect reciprocity.

3.1.2. Structuring step

Structuring is the preparation of teaching materials based on the sequence and systematic of teaching materials. The development of the structure of teaching materials can be carried out in three forms, namely concept maps, macro structures and multiple representations. Making concept maps aims to find out the relationship between one concept and another. Concept maps can help students develop knowledge and connect concepts in their minds to achieve better results [36,37].

Concept maps developed by expert lecturers. The concept map that has been made can be seen in Figure 5.

![Figure 5. Mapping concept of reaction rate.](image)

In addition to the concept map, a macro structure is also made that shows the conceptual position on the building structure of teaching materials. Macro structure is used as a reference for writing teaching materials as a whole. The concepts of reaction rates are mapped into two dimensions, namely vertical and horizontal. The vertical dimension in the form of a downward flow shows the macro concept, while the horizontal dimension in the form of a groove to the right shows the micro concept (subordinate)[38]. The macro structure prepared has gone through the stages of the review and advice from expert lecturers. The macro structure arranged is shown in Figure 6.
Chemical representation has three levels, namely macroscopic, submicroscopic and symbolic [39]. Macroscopic level is a phenomenon that can be observed directly, submicroscopic level provides an explanation at the particulate level where the material described consists of atoms, molecules and ions, while symbolic levels involve the use of symbols, formulas, equations, images and diagrams. The results of the concept of reaction rate selection from textbooks are represented in these three levels. Macroscopic levels are arranged based on phenomena that occur in everyday life based on aspects of SETS. Table 4 shows one example of multiple representations that have been made.

**Figure 6.** Macro structure of reaction rate.
Table 4. Reaction rate multiple representation.

| Concept | Macroscopic | Submicroscopic | Symbolic |
|---------|-------------|----------------|----------|
| Definition of reaction rate | ![Macroscopic Image] | ![Submicroscopic Image] | ![Symbolic Image] |

**Figure 7.** Decreased bromine concentration with time as indicated by waning color (from left to right)

The bromine molecule is a reddish-brown solution. All other species in the reaction are colorless. As the reaction progresses, Br₂ concentration decreases and the color fades.

**Figure 8.** Decreasing number of molecules A and increasing number of molecules B with time

The course of the reaction A → B with an interval of 10 seconds for 60 seconds. At first there were only molecules A (gray circles). Over time, molecule B (red circle) is formed.

The equation for the reaction: \( \text{Br}_2 \text{ (aq)} + \text{HCOOH(aq)} \rightarrow 2\text{H}^+ \text{ (aq)} + 2 \text{Br}^- \text{ (aq)} + \text{CO}_2 \text{(g)} \)

**Figure 9.** Graph of the reaction rate

Reaction rate of A → B, describe as a reduction in molecule A and increase in molecule B with respect to time.

\[
\text{Rate} = \frac{\text{Concentration change}}{\text{Time change}}
\]

or:

\[
\text{reaction rate} = -\frac{\Delta[A]}{\Delta t} = \frac{\Delta[B]}{\Delta t}
\]

3.1.3. Characterization step. The characterization step was carried out after the preparation of the first teaching material was developed in the form of an e-book. Characterization tests through e-books provide a more effective and efficient process in terms of paper use through the use of technology. E-books compiled based on the first draft of teaching materials are accompanied by columns that write the main ideas and options for choosing the characteristics of the text in the teaching material. Not only compiled by loading text, in this e-book also presented several phenomena that are displayed in the form of images and videos that can support the explanation of a text.

At the characterization stage, a comprehension test is carried out where students identify the main ideas of the paragraph in easy and difficult categories, after students get the main ideas that are difficult categories, a didactic reduction phase is carried out which aims to reduce the difficulty of the paragraph main ideas of the material.

3.1.4. Didactic reduction. This step aims to reduce the level of difficulty in teaching materials so that can be easily understood by students. At this step the draft of teaching materials that have been prepared as a result of the step of structuring was reduced by the grid obtained by the characterization stage.

Reducing the level of difficulty of text in teaching materials is carried out in several ways including: 1.) Abandonment, 2.) Use of explanations in the form of images, symbols, sketches, and experiments; 3.) Use of analogies, 4.) Use of historical development levels, 5.) Generalization, 6.) particularization, 7.) Neglecting differences in concept statements, 8.) Return to the qualitative stage.
3.2. Feasibility test of teaching materials

The feasibility test of this teaching material aims to determine the feasibility aspects of teaching materials in accordance with the criteria of the content aspects, linguistic aspects, presentation aspects, graphic aspects of teaching materials, and SETS aspects contained in teaching materials. Analysis of the feasibility data of teaching materials in the form of a questionnaire was conducted by calculating the number of teachers who answered yes and no.

In this study carried out from the selection stage to the structuring stage, then the didactic characterization and reduction stages are still on going. The presentation of this article is part of the results of the thesis research that is still on going.

4. Conclusion

In this study, the development of chemical teaching materials in the reaction rate material in the form of SETS-based e-books with 4S-TMD. The evaluation results of the selection stage indicate that teaching materials are developed in accordance with the demands of the curriculum, scientific truths are guaranteed and the phenomena presented are in accordance with aspects of SETS. The evaluation results of the structuring stage show that the concept map, macro structure and some of the representations developed are valid. The results of the two stages in the first part of this study were draft SETS-based teaching materials.

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