How to Develop Electrochemistry SETS-Based Interactive E-Book?

M Munawwarah*, S Anwar and Y Sunarya
Departemen Pendidikan Kimia, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia

*munawwarah@student.upi.edu

Abstract. This study aims to develop SETS-based interactive e-book teaching material through 4S TMD methodology. The research method in this study is the Development Research (RD) Richey and Klein that consists of design, phase, and evaluation. The design step was to analyze and plan the types of teaching materials instructional developed. There were 12 indicators from 3 standard competencies that produced in selection step based new curriculum, the compatibility subject matter and indicators, and the relations between value and subject matter. Structuring steps yield concept map, macro structure, and multiple representation that were arranged to be first draft of teaching material that was used for develop the instruments for characterization step. Characterization test have been done to students in 12nd grades with 68 texts. Characterization results indicated that there were some texts included to difficult text. Difficult texts have been reduced with the ways back to qualitative steps and particulation. The second draft of teaching material was arranged based the results of didactic reduction of difficult texts. This draft was used for arranged interactive e-book. The characteristics of this SETS-based interactive e-book that developed were mention about the connection between science with environment, technology, and society. This interactive e-book consists of animation, task, and quizzes that taken the interaction of students directly.

1. Introduction
Electrons in an electrochemical cell flows from the anode to the cathode. Electrons from the anode to the cathode will continue to flow until the electron's potential energy in the two half-reactions is equal to one another. An example of a spontaneous reaction is a reaction that occurs between the zinc metal and the copper (II) sulfate solution. The reaction can be written as follows:

\[ \text{Zn (s) + Cu}^{2+} (aq) \rightarrow \text{Zn}^{2+} (aq) + \text{Cu (s)} \]

The electrolysis cell is a reverse reaction of voltaic cells. Electric current needed to generate the redox reaction (electric energy into electrochemical) [1] [2].

Teaching materials is anyone part of the learning resources. Through the good teaching materials, students can be master the competencies in accordance with the speed of learning that they have. Therefore, it was expected that the compiled teaching materials can make students become more active in learning activities to achieving the competences. The guidance about the development of teaching materials said that the instructional materials that were compiled must pay the attention to the demands of the curriculum, that’s meaning the manner of teaching material that we will develop must be in accordance with the curriculum [3]. In the new curriculum, the core competencies and basic competencies have been established by the government, so that all schools can achieve the same
competencies at the end of a particular subject. Therefore, the instructional materials were expected to be used in various schools that implement that curriculum. The good teaching materials are that can be understood by all students with different backgrounds and developments.

There were some method that can be use for develop the teaching material. Anyone of that is 4 steps teaching material development or commonly called with 4S TMD. The steps of development the teaching materials on 4STMD provided clear direction for the researchers in the process of developing the material teaching. Four important steps of this method are the selection, structuring, characterization, and didactic reduction. The steps performed from curriculum analysis to testing the feasibility of teaching materials. Each steps focus on a particular aspect and mutually supports the next stage. After going through a step to next step, it was expected that the next stage will improve the quality of teaching materials that was developed. As the results [5] there was increasing in the level of legibility of teaching materials after the reduction step compared with the results of comprehension test at the characterization step.

The development of teaching materials based on SETS can improve students’ concept comprehension because the presentation of the material was arranged based on daily life [5]. In addition, this approach can also be used in developing teaching materials that present integrated lessons and in accordance with standards of content and competence of graduates [6]. It explains that the teaching materials depend on the current curriculum and the conclusions made from that context [7]. Therefore, through this approach, it was expected that the development of teaching materials can bring students closer to their real life, so that students can solve the problems that were expected to appear in their daily life.

In this study, an interactive e-book was compiled with SETS-based developed using the 4STMD method. The development of this resource have done because most of the existing e-book is just a transfer of printed book into the software format without any interactive aspects in it [8]. Therefore, through the development method, it was expected that the teaching materials in the form of interactive e-book can be compiled to meet the criteria of e-learning materials and criteria set by the National Education Standards Board consisting of the feasibility of content, language, presentation, and graphic [9][10]. Besides that, the interactive e-book composed presents electrochemical material related to science, environment, technology, and society aspects that were directly related to daily life. So that, the purpose of this study is to produce a SETS-based Interactive e-book resource developed by using 4S TMD.

2. Experimental Method
The research method that used in this research is development research method Richey and Klein [11]. This research was used to develop and validate educational products [4]. Figure 1 is a brief overview of Development Research stages in general.

![Figure 1. The steps of development research by Richey and Klein](image-url)

The development process of teaching materials using procedures developed is 4S TMD (Four Step Teaching Material Development). The teaching materials development procedure consists of four steps: Selection, Structuring, Characterization, and Didactic Reduction [12] in accordance with Development Research procedures by Richey and Klein.
Some instruments that used in this study are the selection review instrument, the structuring review instrument, the characterization instrument, and the didactic reduction reviews instrument. The characterization test was conducted in anyone school in Sumedang on 40 students of 12nd grade.

3. Result and Discussion
3.1. The development of teaching material SETS-Based interactive e-book
Teaching material that developed in this study is teaching materials in the form of interactive e-books on SETS-based teaching materials using the steps of development of 4S TMD teaching materials. The four stages consist of the stage of selection, structuring, characterization, and didactic reduction. Each stage has been through the stage of review and evaluation phase. Interactive e-book development is done twice after the characterization stage and after the didactic reduction stage. The e-book produced after the characterization stage is the first draft of the teaching material used for the characterization stage. The e-book produced after the didactic reduction stage is a product of the development of teaching materials.

The steps of interactive e-book development through 4S TMD are:

a. Selection step
Selection step was divided into two part: the first part consisting of the contents standard on the curriculum related to the development indicators of matter, subject matter sources related to the identification of the concepts with the indicators, as well as the value related to chemicals. The second step of selection consists of conceptual analysis with value, compilation of teaching materials, and instruction material revisions. Selection step is more specific on the material delivered on the teaching materials that is related to the grid on the teaching material, the collection of material, and the linkage between competences and indicators to be achieved. The three basic competencies were selected in this selection process which developed into 12 indicators used as the basis in the selection of appropriate concept labels on teaching materials. The results of the formulation of these indicators can be seen in the table below.

| Basic Competencies | Indicator |
|--------------------|-----------|
| 3.3 To evaluating phenomenon or process that occurs in an electrochemical cell sample (voltaic cells and electrolysis cells) that used in daily life. | 1. Explain the meaning of redox and electrochemical reactions |
|                    | 2. Write down the steps of equalizing the redox reaction equation by using half-reaction and the change of oxidation number |
|                    | 3. Mention the component of voltaic cell |
|                    | 4. Write down the reaction on the voltaic cell, cell notation, and determine the standard cell potential value of a redox reaction |
|                    | 5. Determine the spontaneity of redox reactions by using reduction potential data |
|                    | 6. Mention the voltaic cell utilization in daily life |
|                    | 7. Describe the components and types of electrolysis cells |
|                    | 8. Mention the electrolysis cell utilization in daily life |
| 3.4 Analyze the factors that influence the occurrence of corrosion and propose ideas / ideas to overcome them. | 9. Describes the reaction that occurs in the corrosion process |
|                    | 10. Analyzing the factors that cause corrosion |
|                    | 11. Propose ideas on how to solve / prevent corrosion. |
| 3.5 Applying the law / rules in the relevant calculation electrochemical cell. | 12. Resolving issues related to the stoichiometry of the electrolysis and the voltaic cell by using Faraday's law |
Selection step was conducted to ensure the fulfillment of the criteria of the teaching materials in accordance with the criteria of the teaching materials consisting of the criteria of conformity to the applicable curriculum, the truth of the concept of the scientific aspect, the usefulness of the students, the suitability of the available time and the delivery of important concepts studied by the students [12]. Some of these criteria are related to the depth and breadth of material to be presented on teaching materials.

b. Structuring step
This step was conducted to determine the systematic preparation of a resource and a first draft teaching materials consisting of a concept map, the macro structure, and multiple representations. Concept maps are arranged to show the relationship of a concept with another concept clearly. Concept map was arranged from general concept to the specific concept [13]. Therefore, through the whole concept maps that students can develop the knowledge, explore and explain their views, connects the concept of their thinking, to achieve better results [14]. The concepts that were connected through a concept map is based on three basic competencies, which has been mentioned in the earlier stages in the selection. The three sub themes consist of redox reactions, voltaic cells, and electrolysis cells.

Macro structure shows a macro concept (subject matter) in a material equipped with micro (subordinate) concept of macro concept. The macro structure is used to control the writing of the text of the material as a whole. Therefore, each subject in the teaching materials were analyzed and compiled with the text representation model in the form of macro-structure of the text [15]. Multiple representation is the presentation of chemicals in teaching materials consisting of macroscopic, submicroscopic, and symbolic aspects [16][17]. Not only understand on representation level, but also students can conducted every single steps.[18][19][20][21].

Teaching materials draft was prepared and through the steps of review and validation of supervisors. Draft teaching materials then used as a reference for preparing the storyboard in preparing an interactive e-book developed with the cooperation of media experts. The e-book of the first draft teaching material was developed and used for the characterization step.

c. Characterization step
The characterization step was performed after the drafting of the first teaching materials developed in the form of an interactive e-book. The characterization test via e-book provides more effective and efficient process in terms of paper use through technology utilization. The interactive e-book compiled based on the first draft of the teaching material is accompanied by a column writing down the main idea and the choice of selecting the characteristics of a text in the teaching material. Not only composed by containing the text only, in this interactive e-book also presented some phenomena that were displayed in the form of images and video that can support the explanation of a text.
The structured characterization step of the text was tested for its understanding. Each student gives an assessment as much as the student's understanding on each text is measured by the text characteristic level (easy, medium, difficult) and the writing of the main idea of the text. The result of the recapitulation of text characterization test of each student was presented in PDF format which is then processed by the researcher. There are 68 total texts tested for this resource and 7 text are classified as text. The following is the text analysis of the characterization step. The difficult texts continue at the didactic didactic reduction step.

| Characteristic | Amount | Percentage (%) |
|----------------|--------|-----------------|
| Easy           | 61     | 89.70%          |
| Difficult      | 7      | 10.30%          |

d. Didactic reduction
This step aims to reduce the level of difficulty in teaching materials so that can be easily to 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. Reduction was done on every difficult text according to the type of difficulty that the text has. The reduction of the difficulty level of the text on the teaching material was done in several ways including: (1) return to the qualitative step; (2) particulate. Draft teaching materials that were prepared after going through the didactic reduction stage were a draft of SETS-based teaching materials (Science, environment, technology, and society).

3.2. Characteristics of an interactive e-book
SETS-based Interactive e-book materials on electrochemical matter is teaching materials that presented in electronic form. Electrochemical material was delivered by linking aspects of SETS aspects of science, environment, technology and society. The SETS pattern used in the development of interactive e-books was connecting science (concept, theory, and law) with SETS as a supplement to the topic in accordance with indicators that have been developed [22][23]. The good chemistry education is that give the students the value of daily life [24]. It shows that a material text presented in this interactive e-book was not directly linked to the four aspects of SETS. In a text only highlighted one or two aspects of SETS while the other aspects are implied.

The interactive aspect of this e-book teaching material is the presentation of the material and its application in daily life in the form of video that will be observed by the students as information in understanding the electrochemical matter. In addition, there were also tasks with feedback given directly to the answers given by the students. Another interactive aspect is the animation and quiz given at each end of the sub-material and the results can be directly known by the students when they have successfully completed the given quiz. In addition to knowing the results of the quiz score, students can also find out the correct answers from the quiz questions they have been working on.

SETS-based interactive e-book on electrochemical material presents the material in an integrated way between matter of chemistry and daily life. The most important aspect of SETS in the development of this interactive e-book is to bring students into situations to utilize the concept of science to the form of technology for the benefit of society [25].

4. Conclusion
Based on the results of analysis and data processing research that has been done, obtained the following conclusions "Interactive E-book" materials on SETS-based electrochemical materials are developed using Four Steps Teaching Material Development method with four steps: selection, structuring, characterization, and didactic reduction. SETS-based Interactive E-book Teaching
material on electrochemical matter” developed by 4S TMD method have the characteristic of simulation, video, task, and quiz display with automatic processing of results.

Acknowledgments
The author would like to thank Mr. Sjaeful Anwar and Mr. Yayan Sunarya for providing guidance during this research. The authors also thanked the Director General of Kemendikbud who has provided excellent scholarships used during the research.

References
[1] Bradi, James. Et al. 2015. Chemistry, seventh edition
[2] Chang, Raymond. 2005. Kimia dasar. Jakarta: Erlangga.
[3] Depdiknas 2008 Panduan pengembangan bahan ajar. Direktoral Jendral Manajemen Pendidikan Dasar dan Menengah.
[4] Arifin, Z. 2011 Penelitian pendidikan metode dan paradigma baru. Bandung: PT Remaja Rosdakarya.
[5] Binadja A 2006 Pedoman Pengembangan Silabus Bervisi dan Berpendekatan SETS (Science, Environment, Technology, and Society) atau (Sains, Lingkungan, Teknologi dan Masyarakat) Bahan Pembelajaran Penerbitan Khusus Media MIPA UNNES. Semarang: Laboratorium SETS. Universitas Negeri Semarang.
[6] Budiharti R, Ekwati E Y and Pujayanto 2015 Pengembangan Modul IPA Terpadu berbasis SETS dengan Tema “Pelestarian Lingkungan” (Dalam Tinjauan Validitas Isi). Surabaya: Prodi Pendidikan Fisika JPMIPA FKIP UNS.
[7] Kansanen P and Matti M 2015. Didactic relation in the teaching-studying-learning process. Finland: University of Helsinki Finland.
[8] Kong SC, Chan TW, Huang R and Cheah H M, A review of e-Learning policy in school education in Singapore, Hong Kong, Taiwan, and Beijing: implications to future policy planning. Journal Computer Education. Vol. 1 (1-3): pp 187-212
[9] Kozma R B and Russell J 1997 Multimedia and understanding: expert and novice responses to different representations of chemical phenomena. Journal of Research in Science Teaching, 34(9) 49-68
[10] Pietzner V 2014 Computer based learning in chemistry classes Eurasia Journal of Mathematic, Science, and Technology Education Vol 10 (4) pp 297-311
[11] Richey R C, Klein J D and Nelson W A Develomental research : studies of instructional design and development. http://aect.org/edtech/41.pdf
[12] Anwar S 2014 Pengolahan bahan ajar [hand out perkuliahan]. Unpublish manuscript. Bandung: Universitas Pendidikan Indonesia.
[13] Arifin. 2015. Pengembangan bahan ajar IPA terpadu pada tema udara berbasis nilai religius menggunakan 4 steps teaching material development [Tesis]. Unpublish manuscript. Bandung: Universitas Pendidikan Indonesia.
[14] Okonkwo I 2014 Effect of concept mapping teaching strategy on students’ achievement in environmental concepts in chemistry. International Journal Of Scientific Research. Vol. 3 No. 2277-8179.
[15] Novak J D 1990 Concept maps and vee diagram: two metacognitive tools to facilitate meaningful learning Instructional science 19: 29-52.
[16] Gwen Lawrie & Trevor Appleton. 2011. Using multiple representations to enhance understanding of molecular structure: a blended learning activity. International Journal of Environmental & Science Education. Vol 8, 67-71.
[17] Jaber L D and BouJaoude S 2012 A macro–micro–symbolic teaching to promote relational understanding of chemical reactions. International Journal of Science Education 34 (7) 973-998
[18] Johnstone A H 2000 Chemical education research: Where from Here? *Chemistry Education* 4 (1) 34-48
[19] Winnie Sim Siew L I and Mohammad Yusof Arshad 2014. Application of Multiple Representation Levels in redox Reactions among Tenth Grade Chemistry Teachers. *Turkish Science Education*, Vol 11 issue 3
[20] Treagust D F, Chittleborough G D and Mamiala T L 2003. The role of sub-microscopic and symbolic representations in chemical explanations. *International Journal of Science Education*, 25 (11), 1353-1369.
[21] Tan K C D, Goh N K, Chia L S and Treagust D F 2009 Linking the macroscopic, submicroscopic and symbolic levels: The case of inorganic qualitative analysis. In Gilbert, J.K., & Treagust, D.F. (Eds.), *Multiple representations in chemical education* Springer, pp 137-150.
[22] Pudjiadi A 2007 Pendidikan sains teknologi masyarakat. *Rujukan filsafat, teori, dan praksis ilmu pendidikan*. Bandung: UPI Press.
[23] Bridstock M, Burch D, Forge J, Laurent J and Lowe I 1998 *Science, technology, and society*. UK: Cambridge University Press
[24] Lobo M D, Novell J M 2015 How to prepare didactic experiments related to chemical properties related to chemical properties for primary, secondary and high school. *International Journal of Advanced Research in Chemical Science (IJARCS)* 2 (5) pp 41 – 49
[25] Humairoh F and Wasis 2015 Pengembangan E-Book Interaktif Berbasis Salingtemas (Sains, Lingkungan, Teknologi, Masyarakat) pada Materi Fluida Dinamis untuk Meningkatkan Pemahaman Konsep Siswa dan Penerapannya. *Jurnal Inovasi Pendidikan Fisika (JIPF)*, Vol. 04 No. 02, Mei 2015, 69-75.