Stages of development electronic chemistry book on acid and base use 4S TMD models with STES approach

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Abstract. The purpose of this study was to development electronic chemistry book on acid and base use 4S TMD models with STES approach. 4S TMD models consist of selection, structuring, characterization, and didactic reduction. This study method is the first part of the development of teaching materials which includes selection and structuring steps. The study method is Development Research (DR) that consists of design, development, and evaluation. The design stage was to analyze and plan the types of teaching materials instructional developed. There are 13 indicators from 2 standard competencies that produced in selection step based curriculum, the compatibility subject matter and indicators, and the relations between value and subject matter. Explains the concept of acid-base using standardized textbook sources, and analyzes STES that can be integrated with the concept of acid base. In the structuring step, concept maps, macrostructures, and multiple representations are developed that connect between representations of macroscopic, submicroscopic and symbolic levels. The result of the selection and structuring steps are evaluated by expert lecturers. The first part of the development of teaching materials which includes the selection and structuring steps resulted in a draft of electronic chemistry book on acid-base with STES approach. This study reaches the structuring stage, then characterization and didactic reduction stage will be followed up.

1. Introduction
Times are increasingly changing, especially in education. Education is very important for a country. Educational success can also bring success to a nation. Today the nation demands a nation to prepare the next generation to be able to keep up with the development of science and technology [1]. It is expected that the government can improve the quality of education in order to produce students who have excellent abilities [2]. Technological developments are increasingly advanced and many updates [3,4]. Many children are now accustomed to using digital devices, can easily access anything and share new information in virtual space, and think and process information fundamentally [5–7]. Students not only download files or illegal multimedia software but also online material such as e-books [8]. The development of science and technology plays an important role for humans and the environment [9].

In learning activities have three important things that are interrelated, namely teachers, students and subject matter [10]. The interaction of the three things produces an integrated process, where there is a
transformation of knowledge from the teacher to the students so that students gain learning experience. The researcher wrote a lot about teacher-centered teaching approaches and produced meaningful learning. Not many researchers pay attention to teaching materials. In learning activities, teaching materials are one of the learning media that helps students learn, namely electronic books [11]. Electronic books are electronic books that can be read digitally on computers, e-book readers, cellular phones, or personal digital assistants; when used as an instructional or educational book, it is often called an electronic textbook [12,13]. In the last decade, many e-books in online versions where users can read text through an Internet browser, but recently in an offline version that allows users to read textbooks through special e-book software, which can be downloaded from the Internet and read on electronic devices [14,15]. Electronic books are books that can be used and accepted by users because they are in accordance with the development of existing technology [16,17]. Other electronic book forms include video and audio links. This type of interactivity is more useful for readers than simple conversion of text to PDF files, which is a model that is widely used by publishers [18,19]. Electronic science books that are interesting, precise, and use text that is easy to understand [20,21].

In chemistry learning, students often find it difficult to understand abstract and complex material. Then students need learning resources that can help students easily understand the material [22]. Acid-base is an abstract and complex chemical material [23]. Acid-base material can be explained by examples that can be observed directly or phenomena, without realizing that all around us are acid-base substances [24,25]. By displaying phenomena in learning there will also be a growing concern for the environment in the present age [26]. Therefore teaching materials are needed that can help students understand acid-base material [27], through the development of electronic books it is expected to meet the criteria in the teaching and learning process and meet the criteria set by the National Education Standards Board which consists of content eligibility, language, presentations, and graphics [28].

In learning, there is what is known as the learning approach, one of which is the STES-based approach (Science Technology Environment and Society). This approach can be used in learning that can help students understand chemical learning that is connected with real life so that students explore chemical learning [29,30]. Learners can use teaching materials with the STES approach which is expected to help students to have the ability to see an integrative and also expected that knowledge can be used by students in daily life [31]. The STES approach of students is conditioned to be able to understand and apply science principles to produce technological works followed by thinking to reduce or prevent the possible negative impacts that arise from the emergence of these technological products to the environment and society [32,33].

Good teaching materials are teaching materials that can display material that can be easily understood by students [34]. One method of developing teaching materials is 4S TMD. The 4S TMD method consists of four stages, namely selection, structure, characterization, and didactic reduction. This process is the stage of how teaching materials are processed, prepared, and presented by the teacher as teaching material or ready to be studied by students as independent teaching material. The advantages of using this method in developing teaching materials are not only paying attention to the structuring of the teaching material itself but also paying attention to the characteristics displayed in the teaching material [35].

This article discusses the results of research until the structuring stage, while the results of characterization and didactic reduction stages are still in the stage of data collection. This research is part of the results of my thesis research.

2. Methods
The study method is Development Research (DR) that consists of design, development, and evaluation. The design stage was to analyze and plan the types of teaching materials instructional developed. The design is an analysis activity and makes a product plan that will be made. Analyze needs through literature studies from previous research curricula and journals related to this study. This stage the researcher uses the theme is development electronic chemistry book on acid and base with STES approach. At the development stage, it used the 4S TMD development procedure which consisted of
four stages, namely selection, structuring, characterization and didactic reduction. This article is the first part of the development of teaching materials that includes selection and structurization steps. At the selection stage, the researcher selects material and collects from various sources that are in accordance with the subject matter. Selection of basic competencies based on curriculum and development of indicators on selected basic competencies. Then the material was analyzed and selected and the value selection was carried out using the STES approach which was associated with acid-base material. In this structuring stage, concept maps are made consisting of concept organizing, material, macrostructure, and multiple representations. Types of concept maps are arranged with general concepts located at the top and followed by specific concepts. The material is arranged into a macro structure that contains the most important parts that represent the entire contents of the material. All materials that have been prepared at the selection and structuring stage are then made in the form of draft electronic chemistry book and reviewed by expert lecturers. The following is the research flow of this study.

Figure 1. The teaching materials development flow uses the 4S TMD method with STES values integrated in the DR procedure.

3. Result and discussion

3.1. Characteristics of electronic acid base books with the STES approach

Electronic book with the STES approach to acid-base material were developed using the 4S TMD method which consisted of selection, structuring, characterization and didactic reduction stages. The results of the development using the 4S TMD method are as follows:

3.1.1. Selection. The selection phase consists of three parts, consisting of standard content in the curriculum, then the development of material indicators, selecting the source of subject matter related to the identification of concepts with indicators, and the values of the STES approach related to acid-base material.

The teaching material developed is about acid-base which has two basic competencies based on the curriculum. Two basic competencies were developed into 13 indicators which were used as the basis for
selecting concept labels that were suitable for teaching materials. Development of indicators and identification of concept labels can be seen in the table below.

### Table 1. Development of acid-base’s indicators and concept label.

| Basic Competencies                                                                 | Indicators                                                                 | Concept Label                             |
|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------|-------------------------------------------|
| 3.10 Understand the concepts of acids and bases and their strength and ionizing  | Mention the understanding and properties of acid base                      | Definition and properties of acid base     |
| equilibrium in solution                                                          | Explain the concept of acid base according to Arrhenius’s theory           | Arrhenius’s acid base theory              |
|                                                                                  | Explain the concept of acid base according to Brønsted-Lowry theory        | Brønsted-Lowry acid base theory           |
|                                                                                  | Explain the concept of acid base according to Lewis                        | Lewis acid base theory                    |
|                                                                                  | Explain the meaning of acidity (pH)                                       | Understanding acidity (pH)                |
|                                                                                  | Explain the concept of pH                                                  | The concept of pH                         |
|                                                                                  | Explain the concept of degree of ionization                                | Degree of ionization (α)                  |
|                                                                                  | Explain the concept of constant equilibrium water (Kw)                    | Water balance constant (Kw)              |
|                                                                                  | Explain the concept of acid equilibrium constant (Ka) and base equilibrium constant (Kb) | Acid equilibrium constant (Ka) and base equilibrium constant (Kb) |
|                                                                                  | Mention the pH of various solutions using indicators                       | Acid base indicator                       |
| 4.10 Determining the route of change in pH some indicators extracted from natural   | Calculate pH by observing changes in indicator color in various solutions.  | Route of color change from several indicators |
| ingredients                                                                       | Predict the pH of the solution using several indicators.                  | Determine the pH of the solution using several indicators |
|                                                                                  | Designing and conducting experiments on making acid base indicators from    | Make acid base indicators from natural ingredients |
|                                                                                  | natural ingredients                                                        |                                           |

Can be seen in table 1 there are 13 indicators developed in acid-base material. Indicators based on basic competencies are reviewed by expert lecturers to see conformity between indicators and basic competencies. Determination of concept labels is made to determine the concepts that will be developed for teaching materials. In developing the concept label researchers use several chemical textbooks as a reference to guarantee the scientific truth of each concept. The following seven chemical textbooks used in developing teaching materials are.

### Table 2. Chemical textbooks used in developing teaching materials.

| No. | Author                   | Year | Book Title                                         |
|-----|--------------------------|------|----------------------------------------------------|
| 1.  | Whitten et al            | 2004 | Chemistry Tenth Edition                            |
| 2.  | Martin S. Silberberg     | 2007 | Principles of General Chemistry                    |
| 3.  | Theodore L. Brown        | 2012 | Chemistry the Central Science Twelfth Edition       |
| 4.  | Steven S. Zumdahl &      | 2007 | Chemistry Seventh Edition                          |
|     | Susan A. Zumdahl         |      |                                                    |
| 5.  | Neil D. Jespersen        | 2012 | The Molecular Nature of Matter Sixth Edition       |
| 6.  | Raymond Chang            | 2011 | General Chemistry: The Essential Concepts Sixth Edition |
| 7.  | Ralph H. Petrucci et al. | 2011 | General Chemistry: Principles and Modern Applications |

Continue to analyze and develop the values and skills of the STES approach that are compatible with the concepts of acid base. The values developed in this teaching material include science, technology,
environment and society. Table 2 shows an example of the relationship between the value of the STES approach developed with the concept of acid base.

| No | Concept description | Related value | Value linkage with the concept |
|----|---------------------|---------------|--------------------------------|
| 1. | Acid and base are two chemicals that are very important in everyday life. The word acid itself turns out to be from Latin. In Latin acid comes from the word "acidus" which means "sour". Alkaline or alkali is a term derived from Arabic which means ash. | Technology Environment Society | For example vinegar is one of the acids that we often find in everyday life. In chemistry, vinegar is known as acetic acid (CH₃COOH) and acids have a pH value < 7. |

Source: wikipedia

**Figure 2.** Eating vinegar

The most characteristic characteristic of alkaline is that it feels bitter and slippery. For example on soap which turns out to contain alkaline substances, namely sodium hydroxide (NaOH). Sodium hydroxide is commonly known as caustic soda or fire soda and bases have a pH value > 7.

Source: wikipedia

**Figure 3.** Soap

| 2. | In the nineteenth century, Arrhenius first described acid as a substance that produces hydrogen ions (H⁺) when dissolved in water. While the base according to Arrhenius is a neutral compound which ionizes in water to give OH⁻ and positive ions. | Science Environment Society | For example, hydrogen chloride is ionized in water to produce hydrogen ions, H⁺, and chlorine ions, Cl⁻. Hydrogen ions, H⁺, give acidic taste, turn blue litmus red, and corrode some metals. As in the following reaction

\[
\text{HCl} \ (g) \rightarrow \text{H}^+ \ (aq) + \text{Cl}^- \ (aq)
\]

NaOH is an Arrhenius base because it ionizes in water to produce hydroxide ions (OH⁻) and sodium ions (Na⁺), as in the reaction below

\[
\text{NaOH} \ (s) \rightarrow \text{Na}^+ \ (aq) + \text{OH}^- \ (aq)
\] |
The material developed from the concept label is associated with the STES approach values. So that in teaching materials there are phenomena related to the environment and society found in everyday life. Teaching materials developed with the STES approach can help students understand acid-base material by studying phenomena that are around related to science, technology, environment, and society.

The results of the selection phase were then reviewed by expert lecturers to show that the indicators developed from the basic competency according to the concept label were made and the material descriptions developed were then linked to the values of the STES approach and the phenomena presented were in accordance with the STES aspects.

3.1.2. **Structuring.** The structuring stage is the second stage of developing teaching materials with the 4S TMD method. In the structuring stage, concept maps are made consisting of concept organizing, material, macrostructure and multiple representations. Types of concept maps are arranged with general concepts located at the top and followed by specific concepts. Concept maps can help students develop knowledge and allow students to understand the relationship between 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 the following figure.

![Figure 5. Concept map of acid base.](image-url)
Macro structure is a two-dimensional model of progression and dimensions of elaboration [38]. The dimensions of the progression describe the explanation process about the material, while the elaboration dimension describes the substance of the theme in the material. The material is arranged into a macro structure that contains important parts that represent the entire contents of the material. The macro structure arranged can be seen in the following picture.

Concept labels developed into a description of the concept are then represented into three levels, namely macroscopic, submicroscopic and symbolic. Macroscopic levels explain phenomena, images and events that can be seen and sensed directly, submicroscopic levels in the form of explanations of phenomena presented in a form that cannot be seen directly, while symbolic is the use of symbols, formulas, equations, images and diagrams. Macroscopic levels are arranged based on the phenomena that exist in everyday life based on the values of the STES approach. Table of multiple representations that have been made can be seen in the following table.
### Table 4. Acid base multiple representations.

| Concept                          | Macroscopic | Multiple Representations | Symbolic                      |
|----------------------------------|-------------|--------------------------|-------------------------------|
| Arrhenius's acid-base theory     |             |                          | Acid reaction: HCl (g) →      |
|                                  |             |                          | H⁺ (aq) + Cl⁻ (aq)            |
|                                  |             |                          | Base reaction: NaOH (s) →      |
|                                  |             |                          | Na⁺ (aq) + OH⁻(aq)           |

In the nineteenth century, Arrhenius first described acid as a substance that produces hydrogen ions (H⁺) when dissolved in water.

While the base according to Arrhenius is a neutral compound that separates or ionizes in water to give OH⁻ and positive ions. NaOH is an Arrhenius base because it dissociates in water to produce hydroxide ions (OH⁻) and sodium ions (Na⁺).

For example, hydrogen chloride is ionized in water to produce hydrogen ions, H⁺, and chlorine ions, Cl⁻. Hydrogen ions, H⁺, give acidic taste, turn blue litmus red, and corrode some metals. Arrhenius acid is an ionized substance when dissolved in water to give H⁺, or hydrogen ions. Arrhenius bases are substances that give OH⁻ ions, or hydroxide ions when dissolved in water.

![Figure 7. Arrhenius's definition of acid base](image)

The results of the development of the structuring stage were then reviewed by expert lecturers who stated that the concepts, macro structures and multiple representations developed were appropriate. The results of multiple representations are arranged into draft electronic teaching materials.

3.1.3. **Characterization.** At this characterization stage, identification of concepts is carried out, the selection of texts that are difficult or easy on teaching materials by students. At this stage, each concept will be assessed by the level of difficulty of the students. Characterization is needed so that teaching materials that are difficult can be processed specifically in accordance with the views of students.

3.1.4. **Didactic reduction.** In this didactic reduction phase, the characterization of the text at the characterization stage was analyzed by the type of reduction that was in accordance with the characteristics of the difficulty of the content. Reducing the level of difficulty of text in teaching materials is carried out in several ways including Abandonment; Use of explanations in the form of images, symbols, sketches, and experiments; Use of analogies; Use of historical development levels; Generalization; particularization; Neglecting differences in concept statements; Return to the qualitative stage.

In the next characterization phase, a comprehension test will be conducted, where the draft electronic book from the structuring stage will be given to students to identify the main ideas of each
paragraph categorized as difficult or easy to use an understanding test instrument. Furthermore, in the reduction phase is active, where the results of the understanding test have been found that the main ideas in the paragraph that are difficult to reduce become easy paragraph main ideas.

After doing the didactic reduction, the main idea of the paragraph is difficult to change so that the draft teaching material is obtained. The next stage is the evaluation where the test is carried out by students and teachers. Students reassess the main ideas in the paragraph while the teacher identifies the feasibility of teaching materials. The feasibility test is in the form of a checklist that consists of aspects of content eligibility, material presentation, linguistics, grammar of instructional materials and approach values whether they are appropriate and suitable for use in the learning process. In this study only contains until the structuring stage, where while the results of characterization and didactic reduction stages are will be carried out further.

4. Conclusion
This research regarding the development of chemistry teaching materials in the form of electronics on acid-base material with the STES approach with the 4S TMD method. The results at the selection stage show that the teaching materials developed in accordance with the curriculum and the truth of the concepts are guaranteed and the phenomena that are displayed are in accordance with the values of the STES approach. The results of the structuring stage show that the concept map, macro structure and multiple representations developed are appropriate. The results of the selection and structuring stages were made into a draft acidic acid material chemical teaching material in the form of an STES approach. This study reaches the structuring stage, then characterization and didactic reduction stage will be followed up.

Acknowledgments
We thank you to my parents who always support. We also thank Dr. Paed. H. Sjaeful Anwar, M.Sc. and thank you to the friends of the 4S TMD research team.

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