How to develop hydrocarbon e-textbook of chemistry based knowledge building environment with 4S TMD models?

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Abstract. This study aims to describe how to develop hydrocarbon e-textbook of chemistry based knowledge building environment with 4S TMD models. 4S TMD models consists of four stages i.e selection, structuring, characterization and didactic reduction. Hydrocarbon there are many applications in daily life. Knowledge building environment is a theory pioneered by Carl Bereiter and Marlene Scardamalia to construct knowledge. Knowledge building environment contains values that can build knowledge through the environment related to teaching material. The values contained in the knowledge building environment include attentiveness, careness, curiosity, critical, moderation, respect for environment, respect for health and wisdom. Developmental Research was used as method of the study consist of design, develop, and evaluation. In this article, we explain result of developed e-textbook of chemistry in selection and structuring stages. Selection stage consist of the curriculum based on the selection steps, the interrelationships between certain skill value and subject matter. Structuring stage consist of make a concept maps and macro structure. This research only to structuring stage characterization and didactic reduction stages will be carried out.

1. Introduction

Hydrocarbon compounds are compounds composed of carbon and hydrogen atoms. Alkane compounds are saturated compounds that do not contain double bonds and have sp³ hybridization. The general formula for alkane compounds is CₙH₂ₙ₊₂. Alkene compounds are unsaturated compounds that have double bonds π and σ bonds The general formula for alkene compounds is CₙH₂ₙ. Alkyne compounds are unsaturated compounds that have 3 double bonds, 2 double bonds π and 1 bond σ. The general formula for alkyne compounds is CₙH₂ₙ₋₂.

Teaching materials are an important component in learning that can help students achieve indicators in basic competencies [1–3]. Good teaching materials can help students improve understanding and achieve competence. Teaching materials can make students master KI, KD, indicators of achievement of learning outcomes and learning experiences [4–7]. Good teaching materials must be reviewed in the current curriculum. Some methods that can be used to develop teaching materials are using the 4S TMD method. The 4S TMD stages are selection, structuring, characterization and didactic reduction. In the selection stage curriculum analysis is carried out, developing material indicators based on basic competencies, concluding standard concepts to integrating the values of the knowledge building
environment in teaching materials. In the structuring stage, integrating standard concepts into concept maps, macro structures and multiple representations. In multiple representations there are three levels, namely macroscopic, submicroscopic and symbolic [8,9]. Teaching materials that have used submicroscopic can reduce conceptual errors in teaching material [10]. It is necessary to develop teaching materials that fit the curriculum and have the right material concepts. At each stage of 4S TMD each has a role and focus and supports each other. At the characterization stage the teaching material will be grouped into difficult or easy material, each student will be given the opportunity to group teaching material difficult or easy. In the didactic reduction phase aims to change difficult text on teaching materials to be easy so that they can be more easily understood by students [8–10]. It is hoped that after developing teaching materials students can understand hydrocarbon material well because difficult material has been made easier through the didactic reduction stage. Previously difficult material is known through the characterization stage that is assessed directly by students. After going through all stages of 4S TMD, the teaching materials will be tested for feasibility and understanding tests.

The development of knowledge building environment-based teaching materials is useful for increasing student awareness of the environment, health and making students active in learning. The values contained in the knowledge building environment are very good for student learning in the classroom, namely the value of attentiveness, careness, curiosity, critical, moderation, respect for environment, respect for health and wisdom. Knowledge building environment-based teaching materials are highly recommended because they can support the development of student ideas [11–13]. The material in knowledge building environment-based teaching materials is designed in such a way that hydrocarbon material is easier to understand both by using simple language and in everyday materials added everyday phenomena.

Teaching materials have significantly increased the development of electronic teaching materials among other teaching materials e-textbooks , e-book, and e-learning [14–26]. The e-textbook was compiled based on knowledge building environment-based teaching materials using the 4S TMD method. This e-textbook is expected to facilitate students to learn because e-textbooks are more simple and efficient. Students can study hydrocarbons at any time and by using an e-textbook. The method of developing 4S TMD-based teaching materials is expected to improve student understanding because teaching materials refer to everyday phenomena. According to Department of Education and Culture said that students must possess and display the value of building knowledge through the environment of the KBE (knowledge building environment) from the environment found in everyday life or in the environment where they live. Knowledge building environment helps increase students' conceptual knowledge [27]. Knowledge building environments that are implied in teaching materials can help improve the development of student knowledge [13]. In addition, the compiled e-textbook presents hydrocarbon material related to the values of the knowledge building environment. The values contained in the knowledge building environment are attentiveness, careness, curiosity, critical, moderation, respect for environment, respect for health and wisdom. The values of the knowledge building environment contain everyday phenomena that can be integrated in teaching materials. So, the purpose of this study is to produce knowledge building environment-based e-textbook teaching materials developed using 4S TMD.

2. Methods
The research method used Richey and Klein's development research method. Richey and Klein's development research methods were used to analyze, develop to confirmatory evaluation of teaching materials. The following figure 1 is an outline research method for developing Richey and Klein.

![Figure 1. Steps of developmental research](image-url)
The process of developing teaching materials is found in the "development" section of Richey and Klein’s research. Development of teaching materials using the 4S TMD method (Four Steps Teaching Material Development). The development of teaching materials using the 4S TMD method consists of four stages, namely selection, structuring, characterization, and didactic reduction [29–32]. At the selection stage, the values of the knowledge building environment are inserted, namely attentiveness, careness, curiosity, critical, moderation, respect for environment, respect for health and wisdom. In this article, review the first part of the development of teaching materials that include the selection and structuring stages. In the selection phase it starts with developing hydrocarbon indicators that are in accordance with the applicable curriculum, determine the concept label according to the indicators that have been developed, based on the concept label looking for material in several standard chemical books to determine standard concepts and standard concepts integrated with the values of knowledge building environment. In the structuring stage, concept maps, macro structures and multiple representations were developed. Multiple representations connect material at the macroscopic, sub microscopic and symbolic level. Material in the form of analogues, symbols and images can enhance students' conceptual knowledge [33,34]. Products from the first part in developing teaching materials in the form of draft teaching materials, the draft teaching materials will be evaluated by expert lecturers. Some of the instruments used in this study were review selection instruments and structuring review instruments. The following is explained about the development of teaching materials using the 4S TMD method with the KBE (Knowledge Building Environment) values integrated in the DR (Research Development) procedure in figure 2.

**Figure 2.** The teaching materials development flow uses the 4S TMD method with KBE (Knowledge Building Environment) values integrated in the DR (Developmental Research) procedure.

3. Results and discussion

3.1. Development of e-textbook teaching materials based on knowledge building environment

The teaching materials developed in this study are teaching materials in the form of e-textbooks on
knowledge building environment-based teaching materials using the steps to develop 4S TMD teaching materials. The development of teaching materials consists of four stages consisting of selection, structuring, characterization, and didactic reduction. Each stage has gone through the review and evaluation phase. The development of e-textbooks through two important stages before becoming the expected instructional materials products, namely through didactic characterization and reduction stages. At the characterization stage teaching materials are grouped into certain categories, if there are deficiencies in the characterization stage it will be corrected in the didactic reduction stage. After the deduction stage, it is expected that the teaching materials will be appropriate and expected to be used by students.

The steps for developing the knowledge building-based e-textbook through 4S TMD are:

3.1.1. Selection stage. The selection stage consists of several stages, starting with analyzing standard content in the curriculum to developing material indicators, determining label concepts based on material indicators and then collecting various material sources from several chemical books and then taking standard concepts from each book. The standard concept is inserted values related to the knowledge building environment. After all is made, then it is an analysis of the suitability of the basic competencies with indicators, the suitability of indicators with the concept label, the suitability of the concept label with the description of the concept, the suitability of the conceptual description with the values of the knowledge building environment. One basic competency was chosen in this selection process which was developed into 14 indicators. The results of the development of indicators and labels can be seen in table 1.

Table 1. Development of indicators and concept labels on hydrocarbon materials.

| Basic Competencies Indicator | Indicator | Concepts Labels |
|------------------------------|-----------|----------------|
| 3.1 Analyze the structure and properties of hydrocarbons based on the peculiarities of carbon atoms and their compounds. | 1. Explain the peculiarities of carbon atoms | 1. Carbon atoms |
| | 2. Distinguishing saturated hydrocarbon compounds and unsaturated hydrocarbon compounds. | 2. Hydrocarbon compounds |
| | 3. Explain the structure of alkane compounds. | 3. Saturated hydrocarbons |
| | 4. Determine the structure of alkane compounds. | 4. Unsaturated hydrocarbons |
| | 5. Identify the physical properties and chemical properties of alkane compounds. | 5. Definition of alkane compounds |
| | 6. Explain the structure of alkenes. | 6. Name the alkane compound |
| | 7. Determine the structure of the alkene compound. | 7. Physical and chemical properties of alkane compounds |
| | 8. Identify the physical properties and chemical properties of alkenes. | 8. Definition of alkene compounds |
| | 9. Describe the structure of alkyn compounds. | 9. Name the alkene compound |
| | 10. Determine the structure of alkyn compounds. | 10. Physical and chemical properties of alkyn compounds |
| | 11. Identify the physical and chemical properties of alkyn compounds. | 11. Definition of alkyn compounds |
| | 12. Describe the isomer of hydrocarbon compounds | 12. Nomenclature of alkyn compounds |
| | 13. Distinguish the types of reactions of hydrocarbon compounds | 13. Physical and chemical properties of alkyn compounds |
| | 4.1 Make visual models of various structures of hydrocarbon molecules that have the same molecular formula | 14. Test the presence of C elements in organic compounds through experiments |
| | | 19. Presence of element C in hydrocarbons |
Based on the standard textbook, the material description is obtained. The material description obtained from standard textbooks was developed into a standard concept. The standard concept is integrated with the values of the knowledge building environment in accordance with hydrocarbon material. The values of the knowledge building environment are attention, care, critical, respect for the environment, respect for health and policy. Table 2 shows an example of the involvement of conceptual descriptions with the values of knowledge building environment in hydrocarbon material.

**Table 2. Linkages to conceptual descriptions with knowledge building environment values.**

| Concept Description                                                                 | KBE values   | Linkages to Conceptual Descriptions and KBE Values                                                                 |
|-----------------------------------------------------------------------------------|--------------|--------------------------------------------------------------------------------------------------------------------|
| Unsaturated hydrocarbon compounds are compounds that consist of carbon and hydrogen atoms that have double bonds. Unsaturated hydrocarbon compounds are compounds that consist of carbon and hydrogen atoms that have double bonds. Unsaturated hydrocarbons are usually called alkyne and alkenes compounds. | Careness     | See further, unsaturated hydrocarbon compounds are compounds consisting of carbon and hydrogen atoms that have double bonds. Unsaturated hydrocarbons are usually called alkyne and alkenes compounds. Can anyone distinguish alkene and alkyne compounds? |
| Ethene                                                                           | Critical     |                                                                                                                   |
| Ethene structure formula :                                                        |              |                                                                                                                   |

The selection phase needs to be done so that teaching materials made in accordance with the curriculum that are currently in force in Indonesia, ensure the correctness of the concepts used in teaching materials, integrate the values of knowledge building environment in teaching materials so as to produce teaching materials that make it easier for students to learn hydrocarbon material.

3.1.2. Structuring phase. The structuring stage is useful for making material on teaching materials easy to understand by students, namely by inserting concept maps, macro structures and multiple representations on teaching materials. Teaching materials that use analogies in the form of images, diagrams, and symbols can improve student understanding in certain material [35]. Concept maps are useful for making connections between concepts so that they are integrated. Concept maps can be arranged based on general concepts to specific concepts. Concept maps can help students develop knowledge to achieve good results in learning. Concept maps are based on the basic competencies described in the selection stage. Concept maps that have been developed are evaluated by expert lecturers. The hydrocarbon concept map can be seen in Figure 3.
Macro structure is a concept used to regulate the writing of material in teaching materials as a whole. Hydrocarbons are mapped into macro structures according to the advice of expert lecturers. Macro structure can help students understand the relationship between students' mind concepts and teaching materials [36]. The macro structure of hydrocarbons can be seen in Figure 4.

**Figure 3.** Concept map of hydrocarbons.

**Figure 4.** The macrostructure of hydrocarbons.
Each material in the teaching material needs to compile multiple representations with macro structures. Students have difficulty in imagining the concept of subject matter so students do not understand the material as a whole [37–39]. By using multiple representations, students are expected to be able to understand teaching materials well. Teaching materials that insert analogies into subject matter such as multiple representations can help students solve conceptual problems [40–42]. The multiple representations used consist of macroscopic, sub microscopic and symbolic. Macroscopic level is a phenomenon that can be observed directly. The sub microscopic level is an explanation of particulates such as atoms, ions and molecules. Symbolic level involves using formulas, drawings, equations, and diagrams. Table 3 is one example of multiple representations.

| Concept               | Macroscopic          | Sub microscopic            | Symbolic                      |
|-----------------------|-----------------------|---------------------------|-------------------------------|
| Hydrocarbon Compounds | ![Macroscopic Image]   | ![Sub microscopic Image]  | ![Symbolic Image]             |
|                       | We often encounter hydrocarbon compounds in everyday life such as plastic, candles and much more. | Hydrocarbon compounds are compounds composed of carbon and hydrogen atoms. | Structure formula of alkane compounds: \( \text{C}_n\text{H}_{2n+2} \) |
|                       |                       |                           | Molecular formula of alkane compounds: \( \text{C}_n\text{H}_{2n+2} \) |
|                       |                       |                           | Molecular formula of alkenes compounds: \( \text{C}_n\text{H}_{2n} \) |
|                       |                       |                           | Molecular formula of alkyne compounds: \( \text{C}_n\text{H}_{2n-2} \) |

The structuring stage is evaluated by expert lecturers. Concept maps, macro structures and multiple representations are adapted to the concept of teaching materials to be developed. After going through the structuring stage, a draft teaching material will be produced, the draft teaching materials need to be improved and reviewed to be as expected. Draft teaching materials are a reference for preparing e-textbooks made in collaboration with media experts. After the draft teaching material in the form of an e-textbook is developed then it can advance at the next stage, namely the characterization stage.

3.1.3. Characterization stage. The characterization stage is an advanced stage after creating an e-textbook. The characterization stage in this study makes it easier for researchers because they have used e-textbooks instead of using paper. In e-textbook there are several phenomena that can make it easier for students to understand the material. In the first draft of teaching materials in the form of e-textbooks there is also a column for making ideas about the material that has been made, namely columns for categorizing instructional materials into difficult or easy categories. Each student will be given the e-textbook and asked to give an assessment regarding the material that has been made in the draft teaching material. Difficult categorized text in the instructional material will be continued in the next stage, namely didactic reduction. At the characterization stage there is a comprehension test in the form of a checklist to determine students’ understanding of teaching materials. Researchers have not been able to provide results from this characterization stage, as previously explained. This research has only reached the stage of structuring and in the process of making teaching materials.

3.1.4. Didactic reduction stage. The didactic reduction stage is very important to do because this stage aims to change difficult text easily so that it can be better understood by students. Didactic reduction stage is a stage to reduce the level of difficulty of a teaching material by considering psychological and scientific aspects so that teaching materials can be understood by students [43]. Reducing the level of difficulty of text in teaching materials in the didactic reduction stage 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. At the didactic reduction stage the draft teaching material which still contains material that is difficult for students to understand will be made simpler, such as changing the language in text into a simpler language and adding phenomena if the material text is still categorized as abstract. Didactic reduction will be carried out on difficult texts according to the type of difficulties contained in the material. After the draft teaching material through the didactic reduction stage, instructional materials are formed in the form of e-textbooks that contain the values of the knowledge building environment.

3.2. Characteristics of e-textbook

Knowledge building environment-based e-textbook material about hydrocarbon material is teaching material that is presented in electronic form. Electronic teaching materials can contribute significantly to students' understanding of chemistry [44]. Hydrocarbon material is explained by integrating the values contained in the knowledge building environment. Researchers incorporate the values of the knowledge building environment such as attentiveness, careness, curiosity, critical, moderation, respect for environment, respect for health and wisdom in the teaching materials developed. Teaching materials that include respect for the environment can help students to foster awareness of the environment [45]. It is expected that the presence of teaching materials in the form of e-textbooks can make it easier for students to understand hydrocarbon material. E-textbooks that can be easily opened anywhere and can facilitate students in learning because students can learn wherever and whenever. Teaching materials in the form of e-textbooks that have been embedded in the values of the knowledge building environment will make students increasingly appreciate health, respect the environment, be active when learning is classy and wise in learning. Teaching materials are categorized as feasible if feasibility tests have been carried out to experts, feasibility tests in the form of a checklist that consists of aspects of content feasibility, material presentation, linguistics, graphical teaching materials and values of knowledge building environment. The categorized teaching materials deserve to reach a minimum score of 70% [46].

4. Conclusion

Based on the results of analysis and data processing research that has been done, obtained the following conclusions "develops hydrocarbon e-textbook of chemistry based knowledge building environment with 4S TMD models consists of four stages, namely the selection, structuring, didactic reduction stages. The development of a knowledge building environment-based hydrocarbon material e-textbook with the 4S TMD method has different characteristics than other teaching materials, with e-textbook students can easily understand hydrocarbon material because there are several difficult phenomena and explanations when explained by plain text teaching materials. In this study shows that the teaching materials developed have been in accordance with the demands of the curriculum, the truth of the concepts has been tested and natural phenomena have been integrated with Knowledge Building Environment (KBE) values. The evaluation results of the structuring stage state that the concept map, macro structure and multiple representations developed are appropriate. Based on these results, a draft teaching material was obtained which integrated Knowledge Building Environment (KBE) values. In this study only limited to the structuring stage because research is still ongoing.

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