

Development of Structured Essay Diagnostic Test of Chemistry (SEDToC) to Investigate Senior High School Student's Misconceptions on Benzene and its Derivatives

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Abstract—The chemistry material studied in Senior High School has different levels of difficulty. This difficulty is due to misconceptions that occur when students build their knowledge from prerequisite material to complex ones. This study aims to develop a Structured Essay Diagnostic Test of Chemistry (SEDToC) on Benzene and its Derivatives that meet the criteria of a good test instrument and can measure learning outcomes, misconceptions and inhibitory materials. This research procedure consists of three stages, namely (1) defining the content, (2) obtaining information about students' misconceptions, and (3) developing a diagnostic test. The SEDToC development instrument was validated by 5 validators and tested on 20 students who have studied benzene and its derivatives. The results of this study indicate the value of the item validation is 1, the reliability value is 0.91. As for the difficulty index, there are 67% questions with an easy index, 23% with a medium index, and 10% with a difficult index. The value of the discrimination index was found that none of the items was very bad, 32% was bad, 16% was moderate, 35% was good, and 18% was very good out of a total of 57 items. For learning outcomes, only 2 students scored above 80 (Minimum Completeness Criteria). Most of the misconceptions are on questions that require students to determine the nature, nomenclature, and distinguish the structure of benzene and its derivatives. The material inhibiting students in understanding the material of benzene and its derivatives is in the sub material implementing the properties of benzene and its derivatives.

Keywords—Misconception; Learning Outcome; Inhibitory Materials; Benzene And Its Derivatives; Sedtoc

I. INTRODUCTION

The chemistry material studied in Senior High School has different levels of difficulty. The concepts learned are graded from basic concepts to more complex concepts. If students do not understand basic concepts in lower grades, it will affect students' understanding of more complex concepts in higher grades [1]. In the benzene material, students are required to master alkane derivatives, hydrocarbons, and chemical bonds. However, based on the results of the research test, benzene is one of the most difficult topics for students to understand [2][3]. Based on the results of preliminary tests conducted on Senior High School chemistry teachers, who came from nine Senior High Schools in West Sumatra, it was stated that students had difficulty in determining the nomenclature, structure, and reactions that occur in benzene and its derivatives. This difficulty is due to misconceptions that occur when students build their knowledge from prerequisite material to benzene and its derivatives [4].

Misconceptions were analyzed using a diagnostic test instrument [5]. There are several types of diagnostic tests such as interviews, open-ended tests, multiple-choice, and multiple-tier. Interview activities have the advantage of getting in-depth information about how high and low the cognitive level of students is, but it takes a relatively long time with a smaller number of students. The open-ended test gets a broader answer but takes a long time to analyze the results. Multiple choice can be used on

many students and has strong validity, while multiple-tier helps teachers get information faster, but behind the advantages of these two types of tests, the possibility of students' answers in guessing cannot be avoided. Although the three-tier and four-tier instruments have added a level of confidence, the possibility of guessing is still there [1][4].

The instrument developed is a Structured Essay Diagnostic Test Of Chemistry (SEDToC) on Benzene and its Derivatives. The structured essay test was chosen because students' answers were more directed and each answer required a limited answer so that it was easier to analyze. The questions presented are arranged in order of knowledge from basic concepts to complex. Thus, in addition to students being able to recognize concepts and misunderstandings in a material, SEDToC can investigate concepts that cause misunderstandings and hinder the development of concepts that cause misconceptions in learning. [1].

This study aims to develop a Structured Essay Diagnostic Test of Chemistry (SEDToC) on Benzene and its Derivatives. The SEDToC instrument is able to measure student learning outcomes, misconceptions, and inhibiting materials, and. The SEDToC instrument is expected to make it easier for teachers to analyze three aspects in one measurement.

II. METHODOLOGY

This research is a type of research and development (R&D) [6]. The research method in this development is based on research that has been developed by David F. Treagust (1988) and later modified by Fitriza et al (2020)[1][7]. With the following development stages:

A. Defining the content

At this stage, there are four steps that must be carried out, including::

- Identifying propositional knowledge statements

In this stage, an analysis of basic competencies and supporting concepts for benzene and its derivatives is carried out based on the Indonesian curriculum.

- Developing a concept map

Concept maps are made hierarchically from basic concepts to benzene and its derivatives based on propositional knowledge statements.

- Relating propositional knowledge to the concept

This stage is carried out by taking into account the compatibility between the propositional knowledge statements and the concept map.

- Validating the content

Propositional knowledge statements and concept maps are validated by material experts and/or high school chemistry lecturers and teachers.

B. Obtaining information about students' misconceptions

This second stage, a preliminary test based on the results of filling out a questionnaire by a high school chemistry teacher. Questionnaires provide questions related to learning outcomes, topics that are difficult for students to understand on benzene and its derivatives..

C. Developing a diagnostic test

At this stage, there are three steps that must be carried out, including::

- Developing a Structured Essay Diagnostic Test of Chemistry

This test was developed on the material benzene and its derivatives. The questions are designed so that the previous question becomes a prerequisite for the next question, which is a question that follows a valid concept map hierarchy.

- Designing a specification grid

This stage is designed to ensure that the instrument developed includes all Propositional knowledge statements in the concept map

- Continuing refinements

This stage is carried out validation, reliability, difficulty index and Discrimination index

The subjects of this study were students of class XII SMA and/or new students who had studied benzene and its derivatives, high school chemistry teachers, and also lecturers in the Chemistry Department of the Faculty of Mathematics and Natural Science, Universitas Negeri Padang. The object of this research is Structured Essay Diagnostic Test of Chemistry (SEDToC) Benzene and its Derivatives.

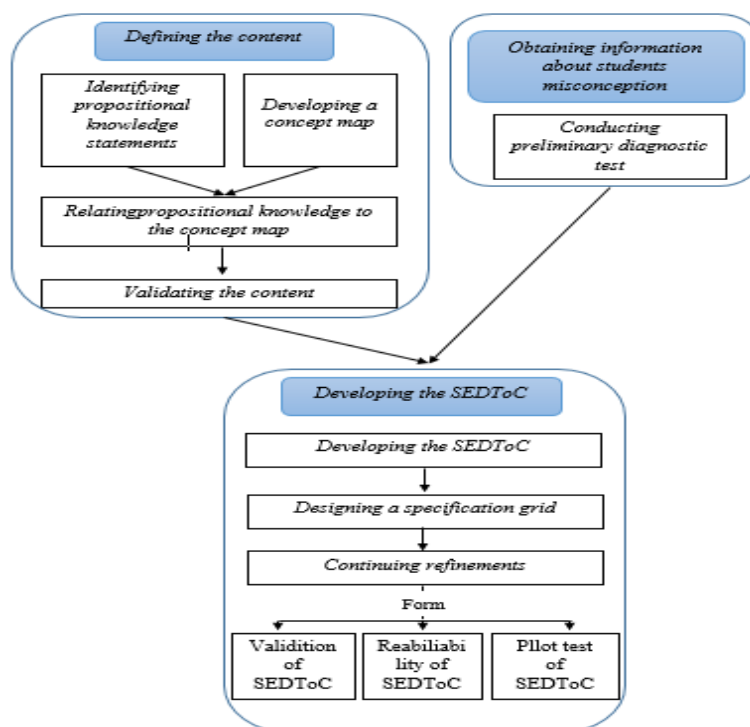


Fig 1. Development method of SEDToC

III. RESULT AND DISCUSSION

First, defining the content starts with identifying propositional knowledge statements on benzene and its derivatives based on the 2013 revised 2019 curriculum [8]. Materials for benzene and its derivatives are covered in Basic Competence 3.11 "Analyzing the structure, nomenclature, properties and uses of benzene and its derivatives". BC 4.11 is not used as the basis for making questions because in this BC it cannot be tested or seen the ability of students through working on questions. [9]. At this stage, all concepts in the material of benzene and its derivatives as well as the related prerequisite concepts are explained based on University level sourcebooks. The related prerequisite materials are alkane derivatives, hydrocarbons, and chemical bonds. In the alkane derivative material, the concept is functional groups, hydrocarbons include aromatic compounds, Kekule structures, electrophiles, and carbocations, while in chemical bonds materials include covalent bonds and polarity. Furthermore, the results of the concept analysis are implemented in the form of a concept map. The concept map is based on a hierarchy of propositional knowledge statements. Where the concept of benzene and its derivatives lies at the top, followed by the concept of derivatives of alkanes, hydrocarbons, and the most basic of chemical bonds. There are 34 concepts from benzene and its derivatives, 15 concepts from alkane derivatives, 4 concepts from hydrocarbons, and 2 concepts from chemical bonds. Related concepts can be seen in table 1 .

Table 1. Concepts in identifying proportional knowledge statements.

Benzene and its Derivatives	Alkane Derivatives	Hydrocarbons	Chemical Bond
Benzene, its derivatives, substitution reaction, monosubstitution, disubstitution, polysubstitution, halogenation, nitration, sulfonation, , alkylation, acylation, orto, meta, para, halobenzene, nitrobenzene, benzenesulfonic acid, an alkylbenzene, an acylbenzene, physical properties, utility, nomenclature, solubility, melting point, boiling point, IUPAC, toluene, phenol, aniline, benzaldehyde, anisole, benzoic acid, phenyl, and benzyl	Functional groups, amine, alcohol, ether, Carboxamide, alkyl, aryl, halogen, aldehyde, ketones, carboxylic acids, esters, nitrate, sulfonic acid, and haloalkane.	Aromatic compounds, electrophiles, carbocations, kekule structures	Covalent bond, polarity

After identifying the propositional knowledge statement and developing a concept map, the two are linked to ensure that the results of the curriculum analysis are following the concept map to ensure that the instrument framework created is consistent. This stage can also be called self-validation before validating with expert validators. Next, carry out validation by the validator using a validation questionnaire sheet. Validation is carried out by chemistry lecturers/experts or chemistry education and chemistry teachers. In the validation of the propositional knowledge statement and concept map, the validated aspects include the suitability between the benzene concept and its derivatives and the prerequisite concepts with Core Competence and Basic Competence, as well as the propositional knowledge statement made by facts/concepts/principles based on chemistry. Content validity is determined using the content validity index (CVI) approach with the formula:

$$CVI = \frac{ne}{N}$$

where,
 CVI = Content Validity Index
 ne = number of experts who rated "valid" or "yes"
 N = total validator

Content validation was carried out by 3 chemistry lecturers from FMIPA UNP and 2 chemistry teachers at SMK-SMAK Padang. Validation was carried out 2 times because there was an improvement in the position of the Huckel law concept. At first, Huckel's law was on the prerequisite material for chemical bonds, then it was suggested to be moved to the position of hydrocarbon material. After calculating, the average I-CVI number identifying propositional knowledge statement and developing a concept map is 1. According to Polit, D.F. & Back (2006) the CVI value is acceptable if it is more than 0.8 [10]. The results of the I-CVI value obtained on the benzene material and its derivatives are more than 0.8 which indicates that the Identifying propositional knowledge statement and developing a concept map developed are declared valid.

Second, Obtaining information about students' misconceptions was carried out by filling out questionnaires by 9 high schools in West Sumatra. The results of the questionnaire analysis found that the average student learning outcomes were 61% from five schools that assessed learning outcomes on benzene and its derivatives. This average is classified as moderate so that the material for benzene and its derivatives is quite difficult to understand for students [9]. The topics that are difficult for students to understand include determining the nomenclature, structure, and reactions that occur in benzene and its derivatives. It can be concluded that broadly speaking, benzene is difficult in every subject.

Third, Developing a diagnostic test begins by making a grid of questions that will be developed based on the stages of Defining the content and Obtaining information about students' misconceptions. The two previous stages are very important to produce a SEDToC instrument that covers all concepts and topics that are difficult for students. While the concept map to pay attention to the arrangement of the questions designed is following the conceptual hierarchy. The next stage is designing a specification grid, the questions that have been designed are outlined in the form of structured questions. The questions that are designed are certain to have limited answers so that they can be interrelated with the next question between the answer to the previous question and the next question. The questions that have been designed are then carried out with continuing refinements in the form of measuring item validity, reliability, difficulty index, and discrimination index. This test aims to produce a good measurement instrument [11].

- Item validity

The validity of the items obtained from the validation results carried out by the previous 5 validators. Validation is carried out using a questionnaire sheet with a Guttman scale with binary questions that only require "yes" and "no" answers for each item [12]. The validity of this item was carried out 2 times so that the data is shown in Table 2. Based on the table of validation results, it can be seen that all the questions that have been designed have an I-CVI average of more than 0.8, so all questions can be said to be valid. The following table of validation results by 5 validators:

Table 2. Item validation results.

Question Number	Validator					ne	I-CVI	Conclusion
	1	2	3	4	5			
1	1	1	1	1	1	1	1	Used
2	1	1	1	1	1	1	1	Used
3	1	1	1	1	1	1	1	Used
4	1	1	1	1	1	1	1	Used
5	1	1	1	1	1	1	1	Used
6	1	1	1	1	1	1	1	Used
7	1	1	1	1	1	1	1	Used
8	1	1	1	1	1	1	1	Used
9	1	1	1	1	1	1	1	Used
10	1	1	1	1	1	1	1	Used
11	1	1	1	1	1	1	1	Used
12	1	1	1	1	1	1	1	Used
13	1	1	1	1	1	1	1	Used
14	1	1	1	1	1	1	1	Used

- Reliability

Reliability is determined by using Cronbach Alpha whose scores are continuous which can be used to measure the reliability of essay tests [13]. Reliability is determined to determine the trustworthiness of the developed instrument. Reliability is calculated after carrying out test tests on 20 students who have just graduated from high school who have studied benzene and its derivatives. With the following formula:

Where,

$$r_{11} = \left(\frac{k}{k-1} \right) \left(1 - \frac{\sum \sigma_i^2}{\sigma_t^2} \right)$$

k = total of essay question

$\sum \sigma_i^2$ = total variance score for each item

σ_t^2 = total score variance

Based on the calculation results, the reliability value of the SEDToC instrument is 0.91. The test instrument is said to be good if it has a Cronbach Alpha reliability value of more than 0.6. So it can be concluded that the confidence level of the SEDToC instrument is very good [6].

- Difficulty index (P)

The difficulty index was analyzed in order to find out how difficult or how easy the SEDToC instrument was developed. The difficulty index value ranges from 0-1, P questions are said to be easy if ≥ 0.7 , and P are difficult if ≤ 0.3 [14]. The results of the analysis of the difficulty index of the SEDToC instrument obtained 67% of questions with an easy index, 23% with a medium index, and 10% with a difficult index of a total of 57 items.

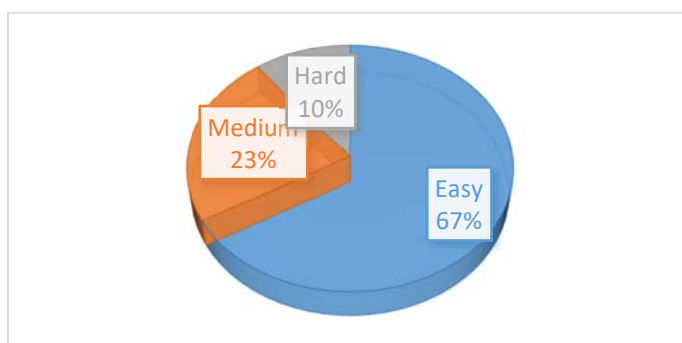


Fig 2. The difficulty index of the developed SEDToC instrument.

- Discrimination indeks

The discrimination index was analyzed to know the ability of the items in distinguishing students from the high group and the low group [15]. The results of the measurement of the discrimination index found that none of the items was very bad, 32% was bad, 16% was moderate, 35% was good, and 18% was very good from the total of 57 items. The graph of the results of the discrimination index analysis can be seen in Figure 3. The bad items can still be used because these items are prerequisite materials that are mastered by students. While the very good items are indicators of achievement of competence from benzene material and its derivatives.

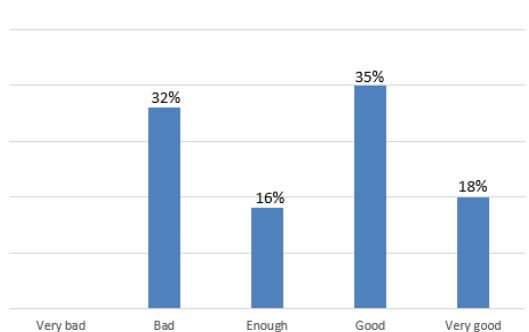


Fig 3. Percentage discrimination index of the developed SEDToC instrument.

The SEDToC development instrument that has been developed on benzene and its derivatives can be used to measure learning

outcomes, misconceptions, and inhibiting materials experienced by students. For learning outcomes, only 2 students scored above 80 (Minimum Completeness Criteria). Meanwhile, 18 students scored below 80. The analysis of students' misconceptions can be seen in Table 3. Based on the table, we can see that students experience the highest percentage of misconceptions on questions that require students to determine the nature, nomenclature, and distinguish the structure of benzene and its derivatives. Only on questions number 3, 10, and 12 there were no students who answered incorrectly. It can be concluded that the material inhibiting students in understanding the material of benzene and its derivatives is in the sub material implementing the properties of benzene and its derivatives.

Table 3. Analysis of students' misconceptions

Indicators of Achievement of Benzene Material Competency and Its Derivatives	Question Number	TMK	M	MK	Criteria
		Percentage (%)			
Understand the structure of covalent bonds	1	0	15	85	Low
Understanding the structure of the kekule	2	0	5	95	Low
Recognize the criteria for aromatic compounds based on Hückel's law	3	0	0	100	Low
Implementing the properties of benzene and its derivatives	4	10	8	82	Low
	5	18	9	74	Low
	7	9	57	34	Medium
Implement the nomenclature of benzene and its derivatives	6	20	9	72	Low
	8	22	37	41	Medium
3.11.1 Differentiate the structure of benzene and its derivatives	9	10	35	55	Medium
3.11.2 Differentiate the nomenclature of benzene and its derivatives	10	10	0	90	Low
3.11.3 Differentiate the properties benzene and its derivatives	11	10	20	70	Low
	13	15	15	70	Low
Understanding the polarity of a compound	12	0	0	100	Low
3.11.4 Differentiate the uses of benzene and its derivatives	14	10	3	87	Low

Where, TMK = don't understand the concept

M = misconception

MK = understand the concept

IV. CONCLUSION

Based on the research conducted, it can be concluded that:

- The SEDToC instrument developed on benzene and its derivatives is following by a good test instrument that meets good validity, reliability, difficulty index, and discrimination index values and has met the criteria of a good test instrument.

- The SEDToC instrument which was developed on benzene and its derivatives has been able to measure learning outcomes, misconceptions, and material inhibiting students in one measurement.

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