

Development of E-Chemistry Laboratory Manual Based on Green Chemistry for High School Student

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Abstract:- This study aims to produce an e-chemistry laboratory manual based on green chemistry, then test the validity, practicality and effectiveness of the e-chemistry laboratory manual. This research method is a development research using the 4-D model. The research subjects were lecturers and chemistry teachers, and high school students. This research instruments used were validation, practicality, and student grade sheets. This e-chemistry laboratory manual was validated by 7 validators, consisting of 4 chemistry teachers and 3 chemistry teachers. The practicality test was conducted by 1 chemistry lecturer, 3 chemistry teachers, and 31 high school students in Padang. This study found that the e-chemistry laboratory manual had a very high level of validity ($v = 0.87$), and the level of practicality by lecturers and teachers ($P = 90\%$) and by students was very high ($P = 87\%$). The use of e-chemistry laboratory manual based on green chemistry in SMA N 1 Painan and SMA N 2 Pariaman is more effective, with effectiveness values of 0.40 and 0.63. The students psycomotor scores by using e-chemistry laboratory manual also increased, with a value of 93%.

Keyword:- E-Chemistry Lab Manual, Green Chemistry, Validity.

I. INTRODUCTION

Chemistry is one of the compulsory subjects taught at the SMA / MA level [1]. Chemistry learning is usually carried out theoretically and experimentally. Experiments aim to strengthen students' understanding of chemistry through various experiments and observations carried out in the laboratory. The combination of theoretical and experimental methods is expected to help students achieve learning goals [2]. However, students still have difficulty understanding the chemistry laboratory manual, because chemistry laboratory manuals are usually presented in text, so they are less attractive to students. In addition, generally the chemistry laboratory manual only consists of discipline in the laboratory and practicum procedures. Students often have problems using practicum tools, and students generally do not understand the physical and chemical properties of the materials used, and how to handle them, especially

hazardous materials. To solve this problem, researcher developed a chemistry laboratory manual in the form of e-chemistry laboratory manual based on green chemistry.

Green chemistry is commonly presented as a set of twelve principles: 1) Prevention of waste/ by-products, 2) Atom Economy, 3) Less Hazardous Chemical Syntheses, 4) Designing Safer Chemicals, 5) Safer Solvents and Auxiliaries, 6) Design for Energy Efficiency, 7) Use of Renewable Feedstocks, 8) Reduce Derivatives, 9) Catalysis, 10) Design for Degradation, 11) Real-time analysis for pollution prevention, 12) Inherently Safer Chemistry for Accident prevention [3]. Conducting procedures in a green way does not make safety precautions irrelevant. Rules such as not eating or drinking in the lab, wearing safety goggles, and avoiding horseplay are still crucial. Once again, even though these experiments are designed to be safer, precautions still need to be observed [4].

This e-chemistry laboratory manual is prepared, complete with pictures of practicum tools and how to use them, physical and chemical properties of the materials used and how to handle them, practicum procedures are presented in the form of drawings and schemes, so that it is interesting and easy for students to understand, and materials used in practicum are materials that are not dangerous and do not produce waste that damages the environment [5]. Researcher hopes that this e-chemistry laboratory manual can help teachers and students in the process of implementing the practicum [6].

II. RESEARCH METHODS

2.1 Type of Research

This research used the type of Research and Development (R&D). The development model used in this research is the 4-D model. This 4-D model consists of four stages, namely definition, design, development and dissemination [7]. The advantages of the 4-D model are the most appropriate basis for developing learning tools, the description is more complete and systematic, and its development involves expert judgment. The development procedure was presented in Figure 1.

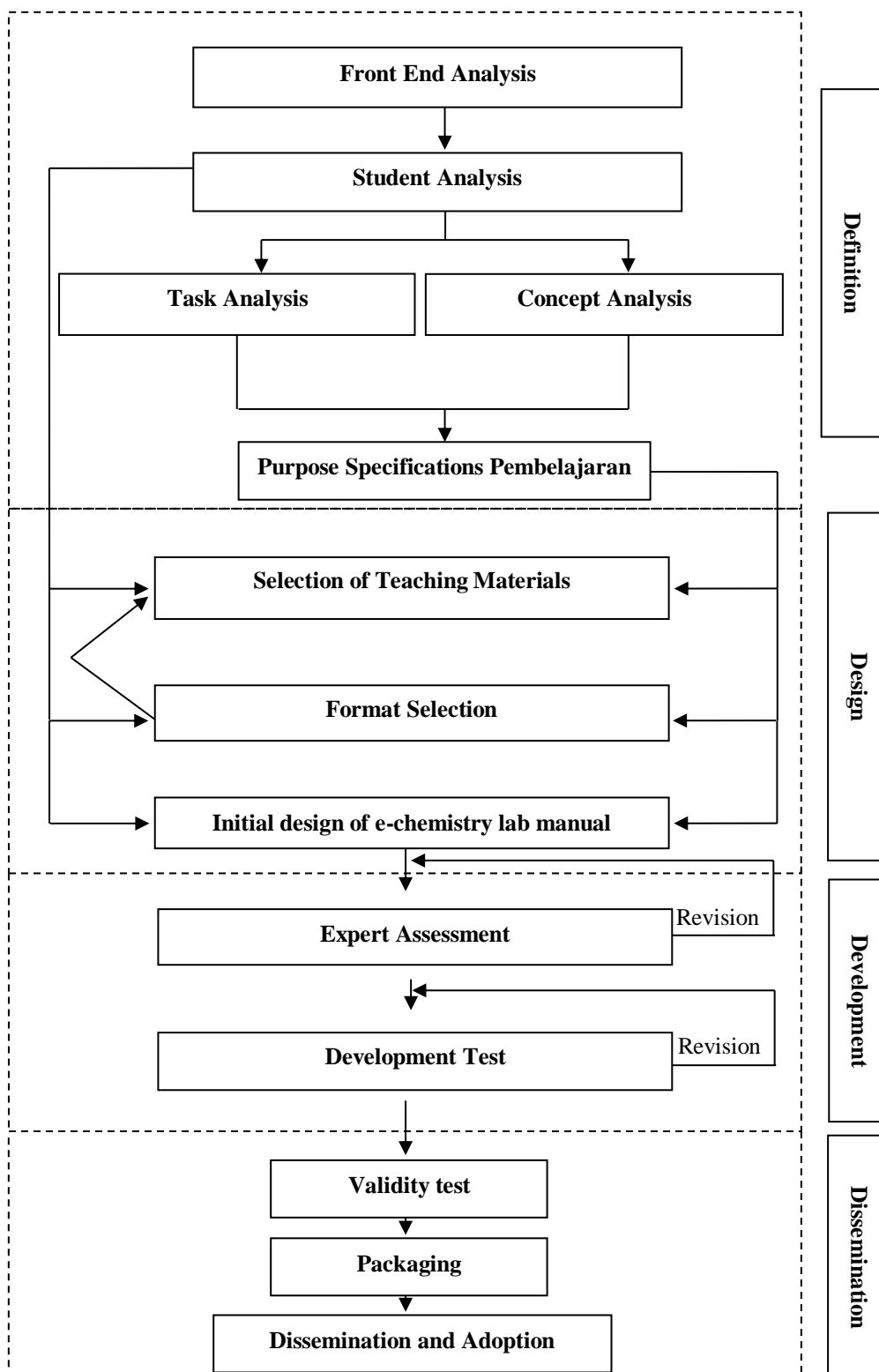


Figure 1. Development Procedure

2.2 Research Subject

The subjects in this study were lecturers and chemistry teachers as validators and practical subjects, and 31 high school students as practical subjects.

2.3 Data Collection

a. Validity Analysis

The validator's assessment of each statement was analyzed using Aiken's V formula. The formula proposed by Aiken is as follows [8] :

$$V = \Sigma s / [n(c - 1)]$$

$$S = r - l_0$$

Information :

l_0 = the lowest number of validity assessments (for example 1)

c = the highest number of validity assessments (for example 5)

r = number given by the assessor

n = number of evaluators

The validation assessment criteria based on the Aiken's V formula can be seen in Tabel 1.

Table 1. Validity level categories

Aiken's V scale	Validitas
$V \leq 0,4$	Less
$0,4 < V \leq 0,8$	Moderate
$0,8 < V$	Valid

b. Practicality Analysis

Data analysis techniques for practicality based on a questionnaire from lecturer, teachers, and students using the following equation :

$$P = \frac{R}{SM} \times 100\%$$

Information :

P = Practicality value

R = Validator's assessment

SM = Maximum score

The practicality level category can be seen in Table 2.

Table 2. Practicality level categories

Score (%)	Practicality
86-100	Very Practical
76-85	Practical
60-75	Quite Practical
55-59	Less Practical

c. Effectiveness Analysis

The effectiveness analysis was seen from the student's score. Effectiveness is expressed in the form of an N-Gain score, using the following equation :

$$N - \text{Gain} = \frac{\text{Posttest value} - \text{Pretest value}}{\text{Ideal maximum score} - \text{Pretest value}}$$

The effectiveness levels expressed as N-Gane are presented in Table 3.

Table 3. N-Gain score categories

N-Gain	Kriteria
$N\text{-gain} > 0,7$	High
$0,3 \leq N\text{-gain} \leq 0,7$	Moderate
$N\text{-gain} < 0,3$	Low

d. Analysis of Psychomotor Value

Analysis of psychomotor value observed from student activities during practicum, using the following equation [9]:

$$NP = \frac{R}{SM} \times 100\%$$

Information :

NP = Psychomotor value

R = Validator's assessment

SM = Maximum score

The practicality level category can be seen in Table 4.

Table 4. Criteria for student psychomotor value

Score (%)	Criteria
81 – 100	Very good
61 – 80	Good
41 – 60	Enough
21 – 40	Less Very
0 – 20	Less

III. RESULT AND DISCUSSION

3.1 Definition

At this stage, identification and analysis of problems experienced by teachers and students are carried out related to obstacles in the chemistry lab process. In addition, researchers also analyzed practicum guides that are commonly used in chemistry lab work. The analysis was carried out, namely front end analysis, student analysis, task analysis, concept analysis, and analysis of learning objectives. Based on the analysis carried out, students have difficulty using practicum tools, students do not understand the nature of the materials used, and students have difficulty following the steps of practicum procedures. This is due to the limitations of the presentation of the chemistry laboratory manual that are commonly used. Therefore, the researcher developed an chemistry laboratory manual to solve these student problems. After this analysis has been completed, the next step is to design an e-chemistry laboratory manual based on green chemistry. [10]

3.2 Design

E-chemistry laboratory manual components based on green chemistry are designed in the form of covers, foreword, introduction to e-chemistry laboratory manual (Green chemistry, laboratory rules, introduction of tools used, work safety, first aid in accidents, laboratory techniques, tools and materials rubric) used, how to make a solution, description of substances), and practicum activities (experiment titles, core competencies, basic competencies, indicators, learning objectives, green chemistry principles used, basic theory, exercise 1, tools and materials, how to work, videos, observation table, discussion sheet, conclusion sheet, exercise 2).



Cover

GREEN CHEMISTRY

Green chemistry adalah suatu cabang ilmu kimia yang berkaitan dengan studi desain produk dan proses dalam mengurangi atau menghilangkan penggunaan zat berbahaya. *Green chemistry* juga meliputi lingkungan alam dan bahan kimia di alam yang berusaha untuk mengurangi serta mencegah pencemaran pada sumbernya. Prinsip *green chemistry* diciptakan untuk menangani masalah-masalah polusi dengan cara alami dan inovatif. Prinsip umum yang mendasari *green chemistry* ini berjumlah dua belas.

1. Pencegahan limbah hasil praktikum lebih baik dilakukan dari pada memproses limbah hasil praktikum yang dihasilkan.
2. Metode sintesis harus didesain untuk memaksimalkan penggabungan semua bahan yang digunakan dalam praktikum menjadi produk akhir.
3. Mensintesis senyawa kimia menggunakan bahan yang lebih aman.
4. Menghasilkan senyawa kimia yang lebih aman bagi lingkungan..
5. Menggunakan pelarut dan mereaksikan senyawa dalam kondisi yang lebih aman.
6. Meningkatkan efisiensi energi dengan cara mereaksikan senyawa kimia pada suhu dan tekanan ruang.
7. Penggunaan bahan dasar yang bisa diperbaharui.
8. Mengurangi terbentuknya senyawa turunan pada reaksi kimia.
9. Penggunaan katalis.
10. Merancang produk kimia yang mudah terurai di lingkungan.
11. Mencegah pencemaran dengan cara menetralkan limbah sebelum dibuang.
12. Meminimalisasi terjadinya kecelakaan.

Principles of Green Chemistry

Cara Kerja

1. Masukkan larutan cuka 25ml ke erlemeyer.

Asam Cuka 25 ml

2. Tambahkan 2 tetes indikator PP.

Indikator PP

How to Work Page

Tabel Pengamatan

No.	Ekstrak Bahan Alam	Warna ekstrak bahan alam	Warna Ekstrak Ketika Ditambahkan Ke											
			Cuka		Larutan baking		Larutan Garam		Larutan gula		Larutan NaOH		Larutan NH ₃	
			T	P	T	P	T	P	T	P	T	P	T	P
1.	Kunyit													
2.	Bunga kembang sepatu merah													
3.	Kentang													

* T : secara Teori
P : secara Praktikum

Observation Table

3.3 Development

At this stage of development, researchers conducted several tests, namely validity test, practicality test, and effectiveness test. In the validity test, the e-chemistry laboratory manual was revised based on the validator's assessment, the revised e-chemistry laboratory manual was used for the next test phase.

a. Validity test

The validity test aims to reveal the level of validity of the e-chemistry laboratory manual based on green chemistry that has been developed. This validity test was carried out by 7 validators, consisting of 4 chemistry lecturers and 3 chemistry teachers. The validation sheet contains 30 aspects of the assessment grouped into content components, construction components, linguistic components, and graphic components. The results of the e-chemistry laboratory manual validation sheet evaluation are then analyzed using the Aiken's V formula. The results of this e-chemistry laboratory manual validation can be seen in Figure 2.

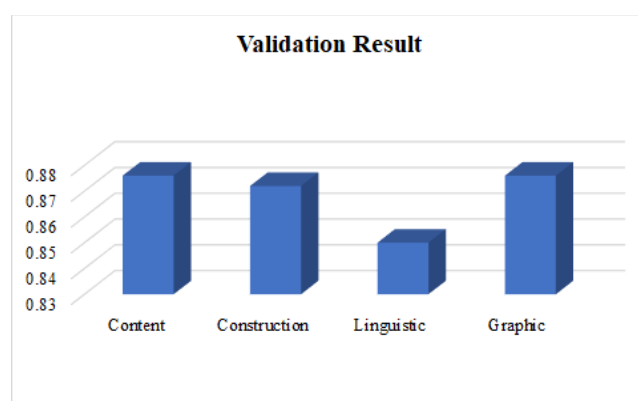


Figure 2. Average validation results

Overall, the validation mean of the experts was $v = 0.87$, which is in the very high category. The results of this validation indicate that the e-chemistry laboratory manual developed is valid. In addition, the experts also provide suggestions for e-chemistry laboratory manual repair. The revised e-chemistry laboratory manual was used for practicality testing.

b. Practicality test

The practicality test aims to determine the level of practicality of e-chemistry laboratory manual based on green chemistry. The practicality test was carried out by 1 chemistry lecturer and 3 chemistry teachers. While the student practicality test was carried out by 31 students. Practicality test assessment consists of ease of use, time efficiency, and benefits [11]. The practicality test results can be seen in Table 5 and Table 6.

Table 5. Results of lecturer and teacher response questionnaires

No.	Aspect	Score (%)	Category
1	Ease of Use	91	Very practical
2	Time Efficiency	91	Very practical
3	The benefits	90	Very practical
	Average	91	Very practical

Table 6. Results of student response questionnaires

No.	Aspect	Score (%)	Category
1	Ease of Use	87	Very practical
2	Time Efficiency	87	Very practical
3	The benefits	86	Very practical
	Average	87	Very practical

In Table 5, the practicality test carried out by lecturers and teachers, the practicality value obtained was 91%, with the very high practicality category. Similar results were also obtained in the practicality test carried out by students (Table 6), the practicality value obtained was 87%, with the very high practicality category. These results indicate that the e-chemistry laboratory manual based on green chemistry is very practical for students to use during practicum.

c. Effectiveness test

The effectiveness test aims to determine the effectiveness of using e-chemistry laboratory manual for chemistry practicum. This test was carried out at SMA N 1 Painan and SMA N 2 Pariaman. The effectiveness of using e-chemistry laboratory manual is determined from the students' cognitive and psychomotor scores. The effectiveness of using e-chemistry laboratory manual based on green chemistry is compared to the commonly used chemistry lab manual. Effectiveness is determined using the N-Gain formula. The N-Gain scores of students of SMA N 1 Painan and SMA N 2 Pariaman in the use of e-chemistry laboratory manual based on green chemistry were 0.40 and 0.63. Meanwhile, the N-Gain scores of students of SMA N 1 Painan and SMA N 2 Pariaman in the use of ordinary chemistry laboratory manual were 0.32 and 0.49. These results indicate that the use of e-chemistry laboratory manual based on green chemistry is more effective. Students' psychomotor scores were obtained when students did practicum. The students' psychomotor scores obtained by students of SMA N 1 Painan and SMA N 2 Pariaman in the use of e-chemistry laboratory manual based on green chemistry were equal to 93%. Meanwhile, the psychomotor scores of students of SMA N 1 Painan and SMA N 2 Pariaman in the use of ordinary chemistry laboratory manual were 77% and 73%. These results indicate that e-chemistry

laboratory manual based on green chemistry improves students' psychomotor abilities during practicum.

IV. CONCLUSION

Based on the research results, the e-chemistry laboratory manual based on green chemistry developed has a very high validity category. In addition, the level of practicality is also very high, so that the e-chemistry laboratory manual based on green chemistry is very suitable for use by teachers and students in practicum. This is confirmed by the results of the effectiveness test. The use of e-chemistry laboratory manual based on green chemistry is more effective and can improve students' psychomotor abilities during practicum.

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