

## DEVELOPMENT OF STUDENT WORKSHEETS GREEN CHEMISTRY ORIENTED TO TRAIN CREATIVE THINKING SKILLS ON REACTION RATE TOPIC

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Received: May 31, 2023. Accepted: June 10, 2023. Published: July 30, 2023

**Abstract:** This study aims to produce student worksheets with green chemistry oriented to train creative thinking skills in matter with reaction rate proper. The green chemistry principles studied in this research are limited to 1, 5, and 12. The research development method uses a 4-D model (define, design, develop, and disseminate) and is limited to the development stage. Limited trials were conducted on 35 students in class XI IPA 1 senior high school. The development of student worksheets is feasible if it fulfills three aspects, including aspects of validity, practicality, and effectiveness. It is declared valid if it gets a minimum mode value of 3 from the range of values 1-5 and is declared practical and effective if the proportion results are  $\geq 61\%$ . The results of the development of student worksheets mean that the feasibility of student worksheets in terms of theoretical validity consists of several things, namely content criteria that obtain a mode value of 5, linguistic criteria obtain a mode value of 5, presentation features obtain a mode value of 5, graphical criteria obtain a mode value 4, green chemistry scoring gets a mode value of 5, and criteria for creative thinking skills gets a mode value of 5. The practicality of student worksheets is seen from the student response questionnaire, which is supported by observations of student activities and the implementation of learning, each of which obtains very practical results with an average proportion of 94.64%, 94.5%, and 98.21%. The aspect of effectiveness is viewed from the results of the creative thinking ability test, which obtained 0.85, which is in the high category. Based on the results of validity, practicality, and effectiveness, it can be interpreted that the student worksheets developed are declared feasible for use in the teaching and learning process.

**Keywords:** *Student Worksheet, Green Chemistry, Creative Thinking Skills*

### INTRODUCTION

Improving the quality of learning is still being pursued in Indonesia to improve the quality of education, including updating the curriculum. The government has established a curriculum listed in Permendikbud No 59 of 2013. The learning model that educators initially realized turned into awareness in students because the mindset had been improved for the development of the previous curriculum [1]. Efforts to improve the quality of education continue with the 2013 curriculum; until now, the newest curriculum, the Independent Curriculum, has been implemented.

The Merdeka Curriculum has a variety of intra-curricular learning that maximizes content so students have enough time to understand concepts and strengthen competence. The Pancasila Student Profile Strengthening Project (P5) can be developed according to certain topics the government determines. The project is not related to the subject content [2]. Implementing the Independent Curriculum in Indonesia follows the era of modernization in which all aspects follow the development of technology and information.

Indonesia is currently following the era of modernization, where all aspects of human activity follow the development of technology and information. Teachers are required to innovate due to the many challenges in education. Every human being must have ten competencies: the ability to solve complex problems, think critically, and think creatively. Four

levels of thinking skills consist of memorizing skills, basic thinking, critical thinking, and creative thinking [3].

The ability to create a solution to a given problem is known as creative thinking skills. Creative thinking allows students to produce various ways and responses to the information given—optimal learning results from students who can solve a problem using many methods individually [4]. There are four characteristics of creative thinking. Creative thinking consists of originality, fluency, flexibility, and elaboration. Creative thinking skills are needed in solving a problem whose application is related to everyday life. Creative thinking skills can be applied to all subjects, including chemistry [5].

Chemistry is one of the subjects focusing on the direct learning process to foster students' understanding in scientifically exploring nature/environment. Learning activities through direct experience (e.g., practicum) is better than memorizing a concept. Current learning activities in which students as learning objects only receive information from educators are obstacles that take time to change. However, educators can use many ways to stimulate students to be active in learning activities by using student worksheets [6].

Learning media in student worksheets can make it easier for educators to display material and foster students to be competent and active during learning activities. Student worksheets contain experiments

using pictures that are in sync with the title of the experiment. Student worksheets contain tools and materials to be used and experimental procedures that can make it easier for students [7].

Chemistry is a subject in which many concepts require students to be involved to understand these concepts. It can be realized through practicum activities where in the practicum process, students are allowed to find out and do so that they can channel the knowledge they already have. A chemical material that contains many concepts and requires a practicum, namely the reaction rate [8].

The reaction rate is one of the materials in the chemistry subject in class XI in the odd semester. Among other subject matter, chemistry is a subject that is difficult for students to understand because this material is factual, conceptual, and procedural [9]. Students often experience difficulty learning the reaction rate material because this material is abstract [10].

The reaction rate is one of the chemical materials in the syllabus so that students easily understand this material; a method or creativity is needed in learning activities. Material for reaction rates is listed in KD 3.7, namely "determining the reaction order and reaction rate constants based on experimental data," and KD 4.7, "designing, carrying out, and concluding and presenting experimental results of factors that affect reaction rates and reaction orders." This material needs practical activities so students more easily understand the material presented [11]. Practical implementation certainly does not escape the use of chemicals that produce waste for the environment and can endanger the safety of students. Therefore, in practical activities, applying the principles of green chemistry is necessary.

Green chemistry is the implementation of principles that suppress the use or formation of hazardous substances in the design, manufacture, and use of chemical products [12]. The principles of green chemistry consist of twelve principles, including waste prevention, atomic economy, synthesis, molecular design, use of safe solvents, use of energy, use of renewable materials, avoiding chemical derivatives, using catalysts, designing chemicals, analyzing in real-time, and reducing the potential for accidents [13].

Chemistry learning in laboratory-based (green chemistry) can increase students' attention to the natural surroundings. Concern for the natural surroundings will foster students' creativity in designing green chemistry-based independent practicums. One chemical material that can apply green chemistry principles is the reaction rate [14].

Based on the results of a student questionnaire on 34 student class XI at a senior high school in the city of Surabaya, it was found that 70.58% of students thought that student worksheets could help in understanding the material. 67.64% of students want student worksheets that contain experimental activities. However, data shows that 73.53% of students do not

know green chemistry. So that as much as 82.35% of students answered that they had never used worksheets equipped with green chemistry principles (green chemistry).

## RESEARCH METHODS

This development research uses a 4-D model (define, design, develop, and disseminate) and is limited to the development stage [15]. A limited trial was conducted using 35 class XI IPA 1 students from a senior high school in Surabaya.

Student worksheets that are developed can be feasible if they fulfill three aspects, namely aspects of validity, practicality, and effectiveness. The process of validating student worksheets was carried out by two UNESA chemistry lecturers and one chemistry teacher at a senior high school in Surabaya by providing validation instruments. The validator assesses each criterion component based on the following Likert scale.

Table 1. Likert Scale

Evaluation	Scale Value
Very inappropriate	1
Not enough	2
Enough	3
Good	4
Very good	5

Based on the table above, ordinal data is obtained and analyzed by finding the mode. Student worksheets are valid if the assessment mode obtained is at least 3 [16].

The feasibility of student worksheets in the practical aspect is seen based on the student's response questionnaire, which is supported by student observation sheets and the implementation of learning. Student response questionnaires are accompanied by "Yes" and "No" answer choices. Students respond to the questionnaire after using the developed student worksheets. Questionnaire results data were assessed using the Guttman scale listed in Table 2.

Table 2. Guttman Scale Criteria

Answer	Positive Statement Score	Negative Statement Score
Yes	1	0
No	0	1

Calculation results based on the Guttman scale are converted into percentages with the formula:

$$\text{Percentage (\%)} = \frac{\sum \text{score}}{\sum \text{score maximum}} \times 100 \%$$

The percentage of student responses is interpreted in Table 3.

Table 3. Student Response Interpretation Criteria

Percentage (%)	Criteria
0-20	Impractical
21-40	Less Practical
41-60	Pretty Practical
61-80	Practical
81-100	Very Practical

Student worksheets are said to be practical based on the interpretation criteria above if the percentage obtained is  $\geq 61\%$ .

The eligibility of student worksheets for effectiveness is seen from the test scores of creative thinking skills. The pretest is carried out at the beginning of learning, while the posttest is carried out at the end of learning after using the developed student worksheets. Test result data can be calculated using the formula:

$$\% \text{ Components of creative thinking} = \frac{\text{Score obtained}}{\text{Total score}} \times 100\%$$

The increase in pretest and posttest data results is then analyzed by calculating the N-Gain using the formula:

$$g = \frac{\text{Score posttest} - \text{score pretest}}{\text{Score maksimal} - \text{score pretest}}$$

The magnitude of the improvement results obtained by students is then interpreted in Table 4.

Table 4. N-Gain Value Index

Mark	Criteria
$g \geq 0.7$	High
$0.7 > g \geq 0.3$	Medium
$g < 0.3$	Low

Student worksheets are said to be effective and appropriate to use based on the above categories if the results of an increase in the test of creative thinking skills get a value of  $\geq 0.3$  which is in the medium category.

## RESULTS AND DISCUSSION

This section will describe the results and discussion of research on developing green chemistry-oriented worksheets to train creative thinking skills on reaction rate material. Student worksheets are feasible if three aspects are met, namely aspects of validity, practicality, and effectiveness. The research method refers to the 4-D development model, according to Ibrahim & Wahyusukartingsih, which is limited to the development stage.

### Define

This stage provides an overview of learning. Determination of the requirements for making learning

materials is namely by analyzing the objectives and discussing the subject matter. This stage consists of five steps: front-end analysis, student analysis, task analysis, concept analysis, and learning objectives analysis.

Things that need to be considered in the front-end analysis are (1) the applicable curriculum, namely the revised 2013 curriculum and the independent curriculum; (2) future demands, such as the need for qualified human resources, namely having high creativity and curiosity.

Student analysis determines student characteristics, including academic ability, age, cognitive development, learning motivation, previous learning experience, and skills. Class XI IPA 1 students as research subjects have an age range of 16-18 years, are in the formal operational stage, and believe that the stage of cognitive development of students at the stage of being able to understand abstract concepts, reason logically, critically and be able to solve problems using systematic experiments [17].

Task analysis aims to identify the tasks that students must do. At this stage, the contents of the student worksheets must follow the Basic Competencies, Competency Achievement Indicators based on the revised 2013 Curriculum.

Concept analysis aims to classify the main concepts that students will learn. Student worksheets are prepared in detail and systematically, where students are guided in obtaining the concepts they learn through practicum activities. The materials developed are the factors that affect the reaction rate.

Based on task and concept analysis objectives, they will be formulated into learning objectives in the reaction rate material adapted to the revised 2013 Curriculum.

### Design

At this stage, the design of learning devices, namely LKPD, is carried out. The main activities in this phase are writing, adopting, making student worksheets, and in-depth guidance with supervisors. This stage consists of selecting the initial format and design.

The format selection aims to examine existing and developed device designs. The format of this tool is following the [18]. Making student worksheets also refers to conformity with the principles of green chemistry and compatibility with the components of creative thinking skills.

Designing is the main activity in developing student worksheets. The initial design of this student worksheet is draft I.

### Develop

The development stage aims to produce a product in the form of a green chemistry-oriented student worksheet with the steps of review, revision of the study results, validation, and trials.

The initial design of the student worksheets was draft I, which was developed and then reviewed by one chemistry education lecturer. The results of the study by the chemistry lecturer are in the form of suggestions or comments for improving the student worksheets that are developed and suitable for use. The student worksheets that have been reviewed are then revised following the suggestions or comments from the reviewers, which are used to make revisions to draft I to produce draft II.

After revising and producing draft II, student worksheets will be assessed through an expert validation sheet. Validation was carried out by three experts, including 2 Chemistry Education lecturers and one chemistry teacher at SMA Negeri 12 Surabaya. The results of validation by experts aim to determine the feasibility of the student worksheets that have been developed.

Student worksheets that have been validated will be tested limited to students. Limited trials were conducted on 35 class XI IPA SMA Negeri 12 Surabaya students.

### Validity

Student worksheets that have been revised, namely draft II, will then be assessed through expert validation sheets. Validation was carried out by three experts, including 2 Chemistry Education lecturers and one chemistry teacher at a senior high school in Surabaya.

Validation data contains student worksheet assessments which are reviewed based on theoretical validity, including criteria for content, language, presentation, graphics, green chemistry principles, and creative thinking skills [19-21]. The validation data obtained is ordinal data, which has the property of not being able to perform mathematical operations (added, subtracted, multiplied, and divided), so the determination is made in mode. So, the student worksheets developed are valid if they obtain a minimum mode value of 3 with an assessment range of 1-5 [16].

Based on the assessment by three validators, the results are obtained in Table 5.

Table 5. Validation Results in Student Worksheets

No	Criteria assessed	Assessment Based on Mode		
		Student	Student	Student
		Worksheets	Worksheets	Worksheets
		1	2	3
1	Content criteria	5	5	5
2	Linguistic criteria	4	5	5
3	Presentation criteria	5	5	5
4	Graphical criteria	5	4	4
5	The green chemistry criteria	5	5	5
6	Criteria for creative thinking skills	5	5	5

Content criteria can be seen from several aspects, namely the suitability of Basic Competency with the 2013 Curriculum revision, the suitability of the reaction level material with indicators and learning objectives, the correctness of phenomena and the material, the compatibility of content with green chemistry principles, and the suitability of content with thinking skills criteria creative. The validation results of student worksheets are presented in Table 5, showing that the feasibility of selecting content for each student worksheet 1, student worksheet 2, and student worksheet 3 is at a value of mode 5, meaning that the category is very good and does not need to be repaired.

Linguistic criteria include four aspects of assessment: writing using easy-to-understand terms, writing student worksheets using short and easy-to-understand language, writing student worksheets using good and correct Indonesian, and writing student worksheets using effective and efficient language. The

results of the validation of the linguistic criteria are attached in Table 5; according to the table above that the student worksheets developed meet the eligibility criteria in the linguistic aspect to get a mode value of 4 for student worksheets 1, which means the category is good and does not need to be repaired, and the mode value 5 for student worksheets 2 and student worksheets 3 means a category is very good and does not need to be repaired.

Presentation criteria include assessing the clarity of objectives, the order of material in systematic student worksheets, the presentation of student worksheets arouses students' motivation and curiosity, and the presentation of material encourages students to be actively involved. The results of the validation of the presentation criteria are in Table 5; based on this table, the student worksheets developed have met the eligibility criteria for the presentation criteria for each student worksheet 1, student worksheet 2, and student

worksheet 3 with a mode value of 5, meaning that the category is very good and does not need to be repaired.

Graphical criteria include aspects of assessing the attractive cover and presenting the contents of the student worksheets, the use of the type of font and text size used to make it easier for the reader, the harmony of the layout of the text and images on the student worksheets, and illustrations and pictures to help understand the concept. The results of the validation of the graphical criteria are in Table 5; based on this table, the student worksheets developed have met the eligibility criteria in the graphical aspect with a mode value of 5 in student worksheet 1, meaning that the category is very good and does not need improvement, the mode value is 4 for student worksheets 2, and student worksheets 3 with the category good and does not need repair.

The green chemistry criteria include aspects containing principle number 1, preventing the formation of waste or garbage; principle number 5, using safe solvents; and principle number 12, minimizing the potential for work accidents in the laboratory. The results of the validation of the green chemistry criteria are shown in Table 5; based on this table, the student worksheets developed have met the eligibility criteria for the green chemistry criteria with a mode value of 5 for each student worksheet 1, student worksheet 2 and student worksheets 3 which are in the very good category and do not need improvement.

Criteria for creative thinking skills include assessment aspects, including originality, fluency, flexibility, and elaboration. The results of the validation of the criteria for creative thinking skills are shown in Table 5; based on this table, the student worksheets developed have met the eligibility criteria for the creative thinking skill component with a mode value of 5 for each student worksheet 1, student worksheets 2, student worksheets 3 are in the very good category and do not need improvement.

### Practicality

The practicality of student worksheets can be obtained from student response questionnaires supported by participant activity observation sheets and the implementation of guided inquiry learning models.

Student response questionnaires were used to determine the practicality of the developed student worksheets. The student response questionnaire contains 32 questions related to content criteria, language, presentation, graphics, green chemistry principles, and components of creative thinking skills. Data on the results of student responses are presented in Table 6.

Based on the table 6, content criteria are the first aspect that supports this. The developed student worksheets received a practical response from students on content criteria. It shows that students understand the material for the reaction rate, the sub-material for the factors that affect the reaction rate are contained in

the student worksheets, seen from the response percentage of 98.57%. The second aspect, namely the linguistic criteria, shows the results are very responsive, seen from the average percentage of 91.42%. The language criterion determines whether the material on the reaction rate, the sub-material on the factors that affect the reaction rate contained in the student worksheets, is easy for students to understand. With language that is easy to understand, the material delivered to students does not cause misconceptions. The third aspect of the presentation criteria gets a percentage of 91.42%. The presentation criteria get very practical responses, seen from the student's ability to understand the contents of the student worksheets. The fourth aspect of the graphical criteria gets a percentage of 99.28% in the very practical category. Students argue that the developed student worksheets are designed to be very attractive and easy for readers to use. The fifth aspect of green chemistry criteria gets a percentage of 97.10% in the very practical category. Students think that the developed student worksheets are designed very well because they apply green chemistry principles. The green chemistry principles used include principle number 1, preventing/reducing the formation of waste; principle number 5, using safe solvents; and principle number 12, minimizing the potential for work accidents in the laboratory. The sixth aspect of the criteria for creative thinking skills gets 89.13% in the very practical category. Students argue that the developed student worksheets can train students' creative thinking skills. However, several aspects get a fairly low percentage, among others, namely determining experimental variables gets a percentage of 85.71%, formulating problems gets a percentage of 82.85%, and formulating hypotheses gets a percentage of 88.57%.

Table 6. Student Response Questionnaire Results

No	Rated aspect	Percentage (%)	Category
1	Content criteria	98.57	very practical
2	Linguistik criteria	91.42	very practical
3	Presentation criteria	91.42	very practical
4	Graphical criteria	99.28	very practical
5	The green chemistry criteria	97.10	very practical
6	Criteria for creative thinking skills	89.13	very practical

Student activities support the empirical validity of the developed student worksheets if relevant student activities are greater than irrelevant ones. Three observers carried out observation of student activity.

The results of student activity analysis observations on student worksheets 1, 2, and 3 are summarized in Table 7.

Table 7. Observation Results of Student Activities

No	Meeting	Percentage of Student Activity (%)
1	Test student worksheets 1 and student worksheets 2	94.45
2	Test student worksheets 1	94.45
	Average	94.45

Table 7 shows the percentage of relevant student activity is 94.45%. Student activities are said to support the practicality of student worksheets if the percentage obtained is  $\geq 61\%$ . Based on Table 4.6, student activities support the practicality of the developed student worksheets.

Student activities were observed regarding the application of green chemistry principles. The green chemistry principles used are principle number 1, preventing the formation of waste; principle number 5, using safe solvents; and principle number 12, minimizing the potential for work accidents in the laboratory. Another activity is creative thinking skills. The components of trained creative thinking skills are originality, fluency, flexibility, and elaboration. The originality component includes activities like formulating problems, determining experimental hypotheses, and making conclusions. The fluency component includes activities like identifying problems and reflecting on problem situations. In the flexibility component, there are activities in determining experimental variables and analyzing data. In the elaboration component, there is the activity of designing an experiment.

Based on the description above regarding student response questionnaires and observation sheets, the LKPD developed was declared fit.

### Effectiveness

The pretest cognitive learning results showed that only some of the 35 students experienced completeness. Students need to understand the material studied fully and then be treated using the developed student worksheets. Furthermore, the posttest results showed that 35 students experienced completeness in the knowledge learning outcomes test. Students are declared to have passed if they score  $\geq 72$  according to the minimum completeness criteria used by one of the senior high schools in Surabaya. The scores obtained by the students were in the range of 72-94, with very good descriptions. That is, students can understand the material factors that influence the reaction rate after going through the learning process using the developed student worksheets [22].

Data from the creative thinking skills test results are used to determine the effectiveness of the developed student worksheets. The results of the

creative thinking skills test were obtained from the results of the student's work on the test sheets in the form of pretest questions and posttest questions. Creative thinking skills include originality, fluency, flexibility, and elaboration [5]. Students who complete get an n-gain score of 0.3-0.7 in the medium to high category.

The pretest results showed that all students needed to improve on the criteria for creative thinking skills. It is because students have never been trained related to creative thinking skills. Then a trial was carried out using green chemistry-oriented worksheets to train creative thinking skills on reaction rate material. The posttest results of students who experienced completeness in each component of creative thinking skills were obtained. Originality thinking skills get an average score of 89.16. Fluency thinking skills get an average value of 87.42. Flexibility thinking skills get an average value of 88.21. Elaboration thinking skills get an average value of 85.00. The following is a table of the results of the increase in the components of creative thinking skills.

Table 8. The Increase in The Components Of Creative Thinking Skills.

Creative Thinking Skills Component	Mark		N-gain
	Pretest	Posttest	
Originality	11.78	89.16	0.88
Fluency	23.42	87.42	0.83
Flexibility	17.85	88.21	0.85
Elaboration	12.19	85.00	0.82
Average	16.31	87.44	0.84

Based on the posttest scores obtained. The originality thinking skill component gets the highest score among other creative thinking skill components. Meanwhile, the elaboration thinking skill component gets the lowest score. It is because students still cannot specify answers based on the questions given.

In terms of cognitive learning outcomes and creative thinking skills, it can be seen that the developed student worksheets meet the criteria of effectiveness seen from the posttest scores of cognitive learning outcomes obtaining a value of  $\geq 72$  according to the minimum completeness criteria and the pretest and posttest results of creative thinking skills from 35 students obtained n -gain score 0.85 with high category.

### CONCLUSION

Based on the results of research and discussion of green chemistry-oriented worksheets to train creative thinking skills on the material of reaction rates in terms of validity, practicality, and effectiveness, it can be concluded that. The results of validity in terms of content criteria get a mode 5 score with a very good category, linguistic criteria get a mode 5 score with a very good category, presentation criteria get a mode 5

score with a very good category, graphical criteria get a mode 4 score with a good category, green chemistry criteria get a mode score of 5 with a very good category, and criteria for creative thinking skills get a mode value of 5 with a very good category. Based on this description, the student worksheets developed were declared valid and suitable. Based on practicality in terms of student response questionnaires, they get very practical categories on all aspects of the assessment criteria. Content criteria 98.57%, linguistic criteria 91.42%, presentation criteria 91.42%, graphical criteria 99.28%, green chemistry criteria 97.10%, and creative thinking skills criteria 89.13%. Also supported by student activity observation sheets of 94.55% and the implementation of learning that was carried out at 98.21%. Based on these descriptions, the developed student worksheets are declared to meet the practicality criteria. Based on the pretest and posttest results of creative thinking skills, an n-gain score of 0.85 was obtained in the high category. While the results of the pretest and posttest learning knowledge get an average completeness score of 90.34. Based on this description, the developed student worksheets meets the effectiveness criteria.

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