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Development Of Teaching Modules With Green Chemistry Oriented To Improve Creative Thinking Skills On Acid-Base Materials

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Abstract: Development Of Teaching Modules With Green Chemistry Oriented To Improve Creative Thinking Skills On Acid-Base Materials. Learning with an independent curriculum requires to be able to master creative thinking skills as outlined in the Pancasila student profile. So this study aims to describe the feasibility of teaching modules with green chemistry to improve creative thinking skills on acid-base materials.The principle of green chemistry used in the teaching module is limited to principle number 1 which is waste prevention, principle no 5 which is the use of safe solvents and principle number 12 is preventing work accidents. The research method used is the ADDIE development model (analysis, design, development, implementation, evaluation). The feasibility of teaching modules is reviewed from validity, effectiveness and practicality. The results showed the feasibility of the teaching module in terms of the validity of the content obtaining a mode score of 5. The construct validity obtains a mode score of 4 so that the teaching module is said to be valid. The practicality of teaching module in terms of learning implementation, student activities and student responses obtained percentages sequentially of 98.91%, 92,41% and 96.42% with very practical criteria. The effectiveness of the teaching module is reviewed from the N-Gain value of 0.89 with a high category.

Keywords: Teaching module, creative thinking skills, green chemistry, acid-base

Abstrak: Pengembangan Modul Pengajaran dengan Orientasi Kimia Hijau untuk Meningkatkan Kemampuan Berpikir Kreatif pada Materi Asam-Basa. *Pembelajaran dengan kurikulum merdeka mengharuskan peserta didik untuk dapat menguasai keterampilan berpikir kreatif yang tertuang dalam profil pelajar Pancasila. Sehingga penelitian ini bertujuan untuk mendeskripsikan kelayakan modul ajar berbasis kimia hijau (green chemistry) untuk meningkatkan keterampilan berpikir kreatif pada materi asam basa. Prinsip kimia hijau yang digunakan dalam modul ajar dibatasi pada prinsip nomor 1 yaitu pencegahan limbah, prinsip no 5 yaitu penggunaan pelarut yang aman dan prinsip nomor 12 mencegah kecelakaan kerja. Metode penelitian yang digunakan adalah model pengembangan ADDIE (analysis, design, development, implementation, evaluation). Kelayakan modul ajar ditinjau dari validitas, keefektifan dan kepraktisan. Hasil penelitian menunjukkan kelayakan modul ajar ditinjau dari validitas isi memperoleh Skor modus 5. Validitas konstruk memperoleh skor modus 4 sehingga modul ajar dikatakan valid. Kepraktisan modul ajar ditinjau dari keterlaksanaan pembelajaran, aktivitas peserta didik dan respon peserta didik didapatkan persentase secara berurutan sebesar 98,91% 92,41% dan 96,42% dengan kriteria sangat praktis. Keefektifan modul ajar ditinjau dari nilai N-Gain sebesar 0,89 dengan kategori tinggi.*
Kata kunci: *Modul ajar, keterampilan berpikir kreatif, kimia hijau, asam basa*

- **INTRODUCTION**

The implementation of education will not be carried out properly without a curriculum that contributes significantly to realizing the process of developing the quality of students. The curriculum in Indonesia has changed ten times since 1947 (Insani, 2019). This curriculum change is adjusted to the increasingly rapid development of the world in various fields, one of which is the field of education, so that a change is made so as not to be left behind with world developments (Angga et al., 2022)

Currently, the curriculum applied is guided by the independent curriculum in accordance with the decree of the Minister of Education, Culture, Research and Technology No. 56 of 2022 as a result of an evaluation of the previous curriculum, namely the 2013 curriculum and as a recovery of learning loss (Menteri Pendidikan Kebudayaan Riset dan Teknologi Republik Indonesia, 2022). The application of the independent curriculum is more flexible and focuses on essential material and character development of students as stated in the Pancasila student profile, with its characteristics, namely there are Learning Outcomes (CP), Learning Objectives Flow (ATP), teaching modules, project-based learning and each class will be divided into several phases (Nurcahyo, 2020). The independent curriculum can be implemented in every subject, one of which is chemistry (Saptono Nugrohadi & Iswatun Chasanah, 2022).

Chemistry is the study of matter and the changes it experiences (Glencoe, 2017). In chemistry there are phenomena related to everyday life and can be explained logically (Saptono Nugrohadi & Iswatun Chasanah, 2022). It's just that in reality chemistry is still often considered difficult by students, because the concepts in chemistry are abstract and complex and in the learning process the material delivered is less associated with everyday life (Sariati, Ni Kadek, Suardana, 2020). One of them is in acid-base material.

Acid-base is a fairly complex material and has many applications in everyday life such as color changes that occur in flowers due to differences in soil pH, the use of household products and medicines (Nurisa & Arty, 2019). Based on Permendikbud No. 08 of 2022, acid-base material is taught in phase F (class XI) with Learning Outcomes in the material are Students are able to observe, investigate and use acid-base concepts in everyday life (Kemendikbudristek BSKAP, 2022). Learning chemistry on acid-base material can be carried out by connecting between the concepts possessed and phenomena in everyday life that are being studied. To be able to understand phenomena related to everyday life, higher-order thinking skills are needed, one of which is creative thinking skills.

Creative thinking skills are one of the skills from the 21^{st} century competency aspects that students must have (Indarta et al., 2022). Creative thinking can be defined as the ability to find ideas, strategies and new ideas in obtaining solutions to a problem (Eko & Mitarlis, 2021). The characteristic of creative thinking skills is that students can smoothly analyze a problem, then propose a new idea or idea and organize all of these things into a problem solving with supporting activities such as practicum activities that can make it easier for students to test previously learned concepts (Babic et al, 2019).

Based on the results of The Global Creativity Index, creative thinking skills in Indonesia are recorded quite low where Indonesia ranks 115^{th} out of 139 countries. The low creative thinking skills of participants are because students are accustomed to learning that tends to be rote rather than understanding concepts related to the phenomena of daily life (Dewi et al., 2019).

One way to improve students' creative thinking skills is to develop learning tools in the form of teaching modules to improve students' creative thinking skills. Teaching module is a new term contained in the independent curriculum. The teaching module has a function in guiding teachers to carry out learning processes that meet the criteria and have been adjusted to the needs of students. The teaching module component contains learning objectives, learning steps, learning media, assessment and learning supporting information (Sufyadi et al., 2021).

The learning media contained in this teaching module is in the form of student activity sheets, this student activity sheets is used to improve students' creative thinking skills with problem-based learning based on everyday life phenomena.

Student activity sheets is also equipped with practicum activities that must be carried out by students as activities that can make it easier for students to prove concepts that have been learned before. This practicum activity cannot be separated from the use of chemicals, the formation of practicum waste and not infrequently work accidents occur during practicum. To reduce this, it is necessary to apply a concept that refers to safe and environmentally friendly practicum activities, one of which is by applying the concept of green chemistry (Nurbaity, 2011). Green chemistry is an innovative chemical concept that focuses on product and process planning that minimizes the use and formation of harmful (Zimmerman et al., 2020). The application of green chemistry in the 21st century is very important because of the many problems that arise, one of which is environmental problems. The purpose of applying green chemistry is to train students to face life challenges, especially on environmental problems (Mitarlis et al., 2017).

The application of green chemistry principles can be realized by designing a chemistry learning that utilizes natural materials in everyday life. With the use of these natural materials, it can maintain the continuity of the chemical learning process without having to rely on artificial chemicals and certainly safer for the environment (Mitarlis et al., 2018). Based on the results of pre-research in one of the high schools in Sidoarjo, it is known that as many as 88.57% of students know about green chemistry. But, the data showed that 51.43% of students answered that they had not applied the principles of green chemistry in practicum activities, so that 62.85% of students had never used learning media equipped with the application of green chemistry principles that had been learned in class X before.

The results of (Naibaho, 2023) research on the development of PBL-based chemistry learning modules in phase F of driving schools get results that are very feasible to be used in learning with a validity value of ainkens'V 0.86 with valid categories, practical results by teachers is 92% with practical sting categories and practical results by students is 91% with very practical categories. However, in Naibaho research only developed PBL-based chemistry learning teaching modules that were not equipped with the application of green chemistry principles, so the development of this teaching module perfected the research to apply green chemistry principles to acid-base materials.

Based on the description above, the purpose of this study is to produce and describe the feasibility of a teaching module based on green chemistry to improve creative thinking skills on acid-base materials.

▪ METHOD

The research method refers to the stages of the ADDIE development model with five stages, namely analysis, design, development, implementation, and evaluation (Branch, 2010). The development stage involves one chemistry education lecturer as a reviewer, two chemistry education lecturers and one chemistry teacher as validators. The implementation stage was carried out in class XI of one of the Senior High Schools in Sidoarjo with a total of 35 students. The research instruments used consist of validation sheets, creative thinking skills test sheets, student response questionnaire sheets, and student activity observation sheets. The teaching module developed is said to be feasible if it meets three aspects, namely aspects of validity, effectiveness and practicality.

The feasibility of teaching modules in the aspect of validity is reviewed from the validity of the content and construct. The validity process of the teaching module uses a validation sheet given to three experts/experts in their fields. The validated data was analyzed using Likert scale.

Table 1. *Likert* Scale Scoring

Valuation	Scale Value
Less Than Once	1
Less	2
Keep	3
Good	4
Very Good	5

(Riduwan, 2015)

The score obtained is determined through the score mode then interpreted according to the scale likert category. The teaching module is said to be valid if the mode score is at least on a scale of 4 or good (Lutfi, 2021). The fasibility of teaching modules on the effectiveness aspect is reviewed from the learning outcomes and tests of students' creative thinking skills in the form of *pretest* and *posttest*. The improvement of pre-test and *post-test* results can be analyzed using the calculation of *n-gain score*, with the formula:

$$< g > = \frac{S_{posttest} - S_{pretest}}{S_{max} - S_{pretest}}$$

Then the results obtained are interpreted in Table 2.

Table 2. N-gain Score Interpretation

Score <g>	Category
<g> ≥ 0,7	High
0,7 > <g> ≥ 0,3	Medium
<g> < 0,3	Low

(Hake, 1998)

The teaching module can be said to be effective if the test improvement results obtained reach ≥ 0.7 with high criteria or ≥ 0.3 with medium criteria. The feasibility of teaching modules in practical aspects is reviewed from the results of student response questionnaires and the results of observations of student activities. Data from student responses and observations of student activities were analyzed using the Guttman scale, where the answer "Yes" got a score of 1, and the answer "No" got a score of 0. Then the number of scores obtained is calculated as a percentage and interpreted into Table 3.

Table 3. Practicality Score Interpretation

Percentage	Category
0 % – 20 %	Impractical
21 % – 40 %	Less Practical
41 % – 60 %	Quite Practical
61 % – 80 %	Practical
80 % - 100 %	Very Practical

(Riduwan, 2015)

The teaching module is said to be practical if the percentage of data analysis results ≥ 61% with the practical category.

▪ RESULT AND DISCUSSION

This research was carried out in accordance with the stages in the ADDIE research model with five main stages:

Analysis Stage

The analysis stage aims to analyze learning needs and identify problems that occur during the learning process. The analysis carried out in this stage is the analysis of curriculum, needs and environment. Curriculum analysis aims to find out the curriculum that is currently applied, see Learning Outcomes (CP) and find out the material learned in class XI so that later it can be used as consideration and adjustment material in the preparation of teaching modules. The application of the independent curriculum is more flexible and focuses on essential materials and character development of students as stated in the Pancasila student profile, so that learning can be adjusted to the needs of students (Sufyadi et al., 2021).

The analysis aims to identify the needs and characteristics of learners during the learning process by taking into account age, academic understanding and cognitive development. Students in class XI have an age range of 14 – 16 years where according to Piaget's theory of development, the age range is at the formal operational stage. This stage students have the ability to think abstractly, ideally and logically in solving a problem (Jarvis, 2011). This is in accordance with the characteristics of creative thinking skills where students can smoothly analyze a problem then propose a new idea or idea and organize all of these things into a problem solving. Environmental analysis is carried out with the aim of obtaining information about the learning environment of students and facilities that can support student activities. As stated by Chayani (2019) where school facilities also affect the learning outcomes of student participants. The learning outcomes of schools with adequate facilities are much higher than schools with inadequate facilities.

As in the ADDIE development scheme, at the analysis stage, an evaluation will be carried out. Evaluation at the analysis stage is advice on the material to be used in the development of green chemistry-based teaching modules and thinking skills that will be applied to research.

Design Stage

The design stage aims to determine the initial framework of the teaching module, the preparation of the *design* and features of the teaching module and the preparation of research instruments

a. Initial framework of the teaching module

The preparation of the initial framework of teaching modules is based on the independent learning curriculum. refers to the Learning Guide and Assessment where there are three components, namely general information which includes the identity of teaching modules, learning objectives, Pancasila Student Profile (P3), lighter questions, facilities and infrastructure, target students. Core components that contain learning activities, assessment, enrichment and remedial, reflection of teachers and learners. Appendices include student activity sheets, reading materials, glossaries, bibliography and assessment rubrics (Sufyadi et al., 2021).

There are three student activity sheets in the teaching module as presented in figure 1 and the student activity sheet in the teaching module component is adjusted to creative thinking skills and the feature of green chemistry principles as presented in figure 2 and figure 3.

Figure 1. Cover Display On Teaching Modules And Student Activity Sheets

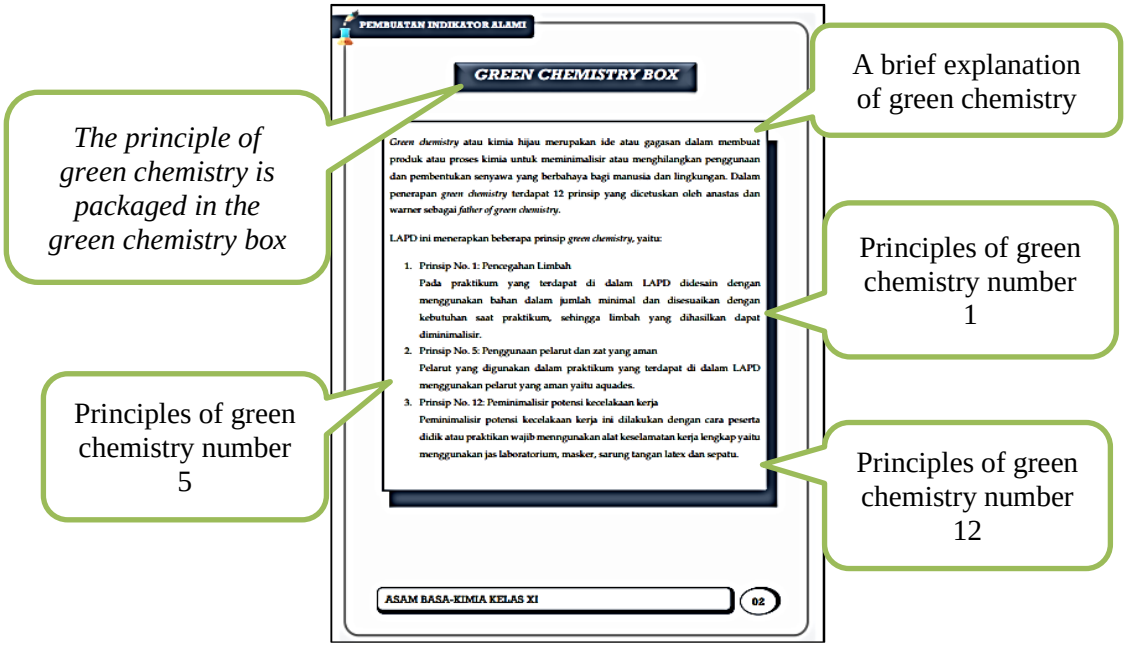

Figure 2. Green Chemistry Principles Display In Teaching Modules Feature

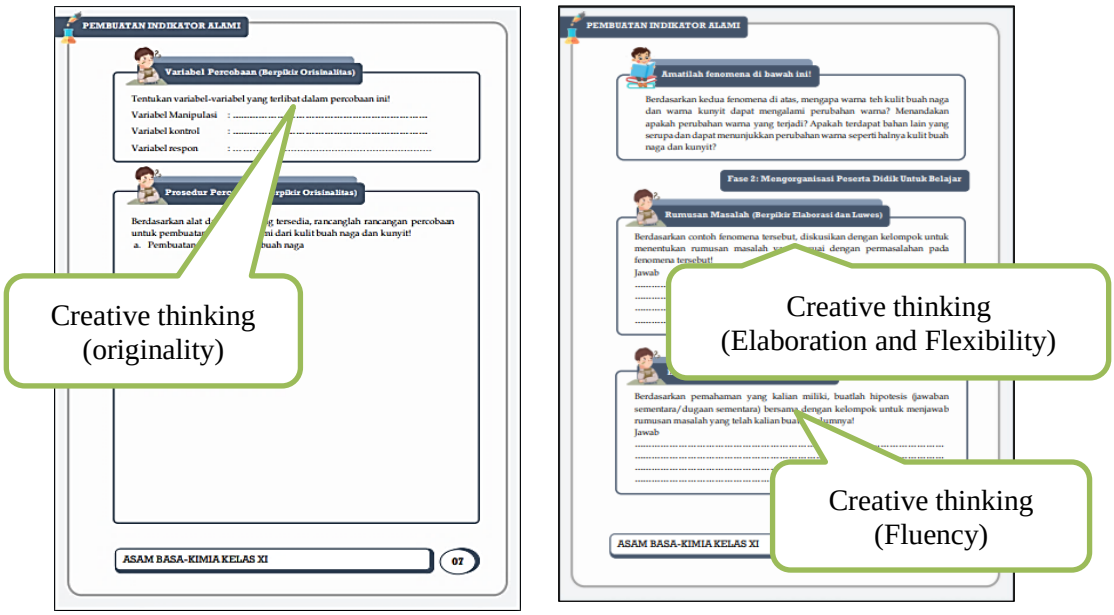

Figure 2. The Example Of Creative Thinking Skills Feature In Teaching Modules

b. Design and features of teaching modules

This stage is carried out by writing and editing the framework of the teaching module that was compiled earlier. This stage will be obtained draft I of the teaching module which lists aspects of creative thinking skills and principles of green chemistry.

The design stage is also evaluated in accordance with the ADDIE research model scheme. Evaluation at this stage is that there are several components in the teaching module and research instruments that need to be improved in accordance with the suggestions and comments of the supervisor.

Developmet Stage

The third stage is the *development* stage. This stage will carry out several study and validation activities by experts to determine the validity of the Teaching Module developed. The initial design produced in the form of draft I will be reviewed by one expert in the field of chemistry and chemistry learning using a study sheet. The results of the study obtained are in the form of comments and suggestions for the basis of revision and produce draft II. Furthermore, draft II will be validated by three validators using validation sheet instruments.

Validity of Teaching Modules

The validity of the teaching modules developed is reviewed from the validity of the content and the validity of the construct (Heale & Twycross, 2015). Validators will give a score of 1-5. Then the score obtained will be determined in the mode to find out the validity of the teaching module.

a. Content validation

The validity of the teaching module content includes the suitability of the teaching module with the independent curriculum, the completeness of the teaching module components and the suitability of the Student Activity Sheet. The results of content validity are presented in Table 4.

Table 4. Content Validation Results Data

No	Assessed Aspects	Score Mode	Category
1	Compatibility of teaching modules with the Independent Curriculum	5	Very Good
2	Completeness of teaching module components	5	Very Good
3	Student activity sheets compliance	4	Good

Based on the results of content validation in Table 4, it shows that in the aspect of module suitability with the independent curriculum and the completeness of the teaching module components, it obtained a mode 5 score with a very good category, while in the aspect of suitability, student activity sheets obtained a mode 4 score with a good category so that the teaching module on the validity of the content can be said to be valid.

b. Construct Validity

Construct validity includes the suitability of teaching modules with presentation, language, and graphics criteria. The results of construct validity are presented in Table 5

Table 5. Construct Validation Results Data

No	Assessed Aspects	Score Mode	Category
1	Conformity of Serving Criteria	5	Very Good
2	Conformity of Language Criteria	5	Very Good
3	Conformity of Graphic Criteria	4	Good

Based on the results of content validation in Table 5, it shows that in the aspect of suitability, the presentation and graphic criteria obtained a mode score of 5 with a very good category, while in the aspect of language suitability, a mode 4 score was obtained with a good category so that the teaching module on the validity of the content can be said to be valid.

In accordance with the validation results that have been obtained, overall the teaching modules developed can be said to be valid. This is in accordance with Lutfi (2021) which states that a product developed is said to be valid if the mode score is at least on a scale of ≥ 4 or good.

Before the implementation phase, the development stage is evaluated according to the scheme in the ADDIE research model. Evaluation at this stage is to improve the draft teaching module in accordance with the suggestions and comments of the reviewer on the results of the study and the validation results of the three validators before testing or implementation.

Implementation Phase

The implementation stage is a trial stage of teaching modules with the aim of knowing the effectiveness and practicality of teaching modules developed based on test results and student response questionnaire results supported by observations of student activities.

a. Practicality of Teaching Modules

The practicality of the teaching module is measured using the results of learning implementation, observations of student activities and student response questionnaires. The implementation of learning using the developed teaching modules was carried out in three meetings. Learning activities in the teaching module developed refer to the learning syntax with the Problem Based Learning model. This learning activity will expose students to a problem in real life and it is hoped that through this learning students can come up with new ideas to solve the problems presented. The results of the implementation of learning activities are shown in Table 6 below:

Table 6. Data from Observation of Learning Implementation

No	Learning Activity	Results of Implementation	
		First Meeting	Second Meeting
1	Introduction		
	Phase 1: Orientation of student to problems	18	20
2	Core activity		
	Phase 2: Organizing Students to Learn	24	24
	Phase 3: Guiding the investigation	8	8
	Phase 4: Developing and Presenting Result	8	8
	Phase 5: Analyzing and Evaluating the Problem Solving Process	12	12
3	Closing	23	23
Total		**89**	**95**
Percentage (%)		**92,70**	**98,91**

Based on the results of learning implementation shown in Table 6, it was found that the results of implementation at meeting one amounted to 92.70% and meeting two amounted to 98.91%. In general, the learning process can be said to be carried out well. Teachers have implemented the PBL learning model even though there are several points that have not been implemented properly. So it can be concluded that learning activities in green chemistry-oriented teaching modules are carried out as a whole and can be carried out well. According with Maulinda (2022) statement which states that the implementation of learning can be carried out properly with the existence of teaching modules arranged according to the characteristics of students so that learning objectives can be achieved properly.

In addition to reviewing the results of learning implementation, the practicality of teaching modules is reviewed through observation of student activities. The results of observations of student activities are obtained from observations made by observers on student activities during the LAPD trial process contained in the teaching module. The results of observations of student activities are presented in Table 7.

Table 7. Data from Observation of Student Activities

Meeting	Percentage (%)	Category
1	88,25	Excellent
2	92,41	Excellent
Average	**90,33**	**Excellent**

The activities of students observed include reading activities and determining problem formulations according to phenomena in everyday life, making hypotheses, determining variables. In addition, learners design experiments by preparing tools, materials and making experimental procedures. Then students do practicum by applying green chemistry principle number 1, which is to reduce waste by measuring and measuring the use of chemicals in accordance with experimental procedures. Principle number 5 uses safe solvents using aquades to extract natural ingredients, and principle number 12 is to prevent work accidents by using low concentrations of chemicals and using personal protective equipment such as lab coats, latex gloves and shoes. As statement from Mitarlis (2017) When students apply the principles of green chemistry, it is hoped that every learning can be applied in the laboratory so that the learning process is safer and can reduce the negative impact caused by the use of chemicals. The next activity is for students to write down the results of observations and discuss with the group to analyze the experimental data which can then be drawn conclusions so that students are able to relate the results of the experiment with the phenomena of daily life being studied.

Based on the observations of these students, it can be seen that student activities get the largest percentage, which is 88,25% in the first meeting and 92,41% in the second meeting. The results of the study obtained are in accordance with the research that Rudibyani & Prabowo (2020) states that the PBL learning model applied can make students more active in learning, asking, expressing their opinions and discussing with friends or teachers.

The practicality of the teaching module can be reviewed based on the results of student response questionnaires. This questionnaire contains several questions that will be distributed to 35 students at the end of the trial stage of the developed teaching module. There are two components in the student response questionnaire, namely student responses to student activity sheet contained in the teaching module and student responses to learning using green chemistry-oriented teaching modules. The data from the questionnaire results of student responses to student activity sheet and Learning using teaching modules.

Table 8. Average Student Response Results

Response Questionnaire	Average	Category
Against the student activity sheet	95,61%	Excellent
Against learning	96,42%	Excellent

Based on the data shown in Table 8, it shows that the student activity sheet contained in the teaching module gets an average percentage of student response of 95.61% with the very practical category and for learning using the teaching module gets an average percentage of student response of 96.42% with the very practical category. In line with the results of the study Widyanti & Rahmawati (2022) which states that there is a positive response to the application of green chemistry in learning so that it can increase students' awareness of environmental problems, especially problems caused by chemicals.

So it can be concluded that the teaching module is said to be practical because the data obtained get an average percentage of ≥ 61%. Each obtained an average percentage of 95.80%, 90.33% and 96.42% in the very practical category.

b. Effectiveness of Teaching Modules

The effectiveness of teaching modules is measured based on cognitive tests and creative thinking skills in the form of pretest and posttest. Pretest is given before learning is carried out using student teaching modules to measure learning outcomes and creative thinking skills of students. Posttest is given after the learning process is carried out using teaching modules to measure the improvement of learning outcomes and creative thinking skills. Cognitive tests and creative thinking skills in the form of description questions totaling 10 questions with the characteristics of the questions referring to acid-base material and creative thinking skills.

The results obtained will be accumulated according to the following formula:

$$\text{Cognitive Test Scores} = \frac{\text{Scores obtained}}{\text{Maximum score}} \times 100$$

and

$$\text{Creative Thinking Skills Score} = \frac{\text{Score per component obtained}}{\text{Maximum score per component}} \times 100$$

The results of obtaining pretest and posttest scores are presented in Figure 3.

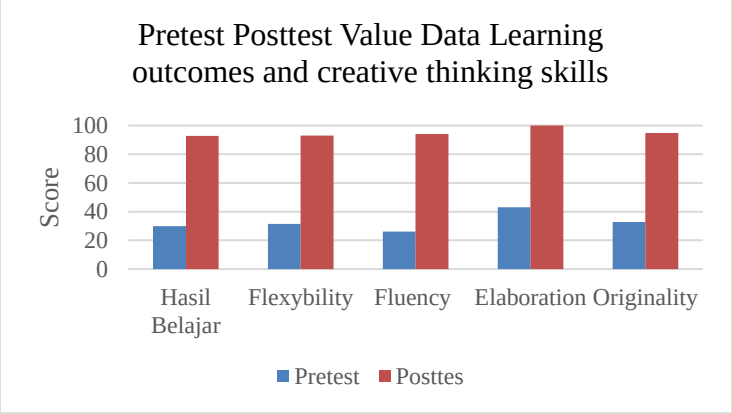

Figure 3. Pretest Posttest Value Data

Based on the data obtained in Figure 3, there is an increase in learning outcomes and creative thinking skills in each component after learning using the developed teaching mode. Initially, students are still not familiar with questions that connect material concepts with problems contained in the phenomena of everyday life, become more accustomed to giving a

problem related to everyday life, then solve the problem based on the results of the experiment. Students also have the opportunity to expand their knowledge through active interaction with peers in solving problems in everyday life with concepts they have learned before.

Then the pretest posttest value is strengthened by conducting an analysis using the N-gain value. The results of the N-gain analysis increased learning outcomes by 0.89 with the high category. While in the flexibility thinking skills component obtained an increase score of 0.91 with a high category, then in the fluent thinking component obtained an increase score of 0.90 with a high category. While the skill of detailing thinking (elaboration) gets the highest increase score of 1.00. Finally, originality skills received an increase score of 0.92 in the high category.

The existence of green chemistry-based teaching modules can make students more active in following learning and can improve the ability of creative thinking skills that are already owned by students where students are required to determine problems, conduct an experiment, analyze data to draw conclusions to solve the problem.

This is in accordance with the objectives of the independent curriculum contained in the Pancasila student profile, where students are actively involved in learning and are able to use creativity and mutual assistance in connecting material concepts and phenomena of daily life (Sufyadi et al., 2021). So that the results obtained show that the use of green chemistry-based teaching modules developed can be said to be effective in improving learning outcomes and creative thinking skills of students.

Evaluation at the implementation stage is in the form of comments obtained from student response questionnaires, and improvements can be made based on existing comments if needed so that the green chemistry-oriented teaching module developed becomes better.

Evaluation Phase

The evaluation stage is carried out at each stage in the ADDIE research model which aims to correct any shortcomings or discrepancies from each stage in order to later obtain better results. This is in accordance with the ADDIE research model scheme proposed by Branch (2010).

▪ CONCLUSION

This study shows the feasibility of green chemistry-based teaching modules to improve creative thinking skills on acid-base materials in terms of validity, effectiveness and practicality. Validity is viewed from the validity of the content with the acquisition of a mode 5 score in the aspect of module suitability with the independent curriculum and the completeness of teaching module components, while in the aspect of suitability LAPD obtained a mode score of 4. The construct validity in the aspect of suitability of presentation criteria and graphics obtained a mode score of 5 while in the aspect of linguistic suitability obtained a mode score of 4. The effectiveness of the teaching module in terms of the increase in learning outcomes and creative thinking skills of students obtained an N-Gain value of 0.89 with a high category. The practicality of the teaching module in terms of student activity and student response obtained a percentage sequentially of 98.82% and 96.42% with very practical criteria.

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