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Integrated Green Chemistry Problem-Based Learning Module Development to Improve Science Process Skills Senior High School Students on Basic Chemicals Law

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Abstract: The implementation of the independent curriculum at the senior high school level can be an opportunity for educators to develop alternative teaching materials that according to the latest curriculum standards. One alternative teaching material that can be used is the module. This study aims to develop a basic chemical law module based on Problem Based Learning integrated with green chemistry that is valid, practical and effective. This type of research is educational development research (educational design research) or known as EDR. The test subjects for this study were three chemistry lecturers, two chemistry teachers, and tenth grade students. The results of the study obtained a construct validity of 0.90 and a content validity of 0.91. The results of practicality tests by teachers and students are included in the very practical group with respective values of 0.88 and 0.84. The results of the t test on student learning outcomes showed that t-count (2.87) is bigger than t-table (1.67), and the value of science process skills in the experimental class was higher than the control class. Therefore, it can be said that the module based on problem base learning integrated with green chemistry on basic chemical law material is valid, practicable, and effective. Therefore, it can be said that the modules made are reliable and useful for use in the learning process.

Keywords: Basic Chemicals Laws; Module; Problem Base Learning; Science Process Skills

Introduction

The independent curriculum is now starting to be implemented in schools, based on the philosophy of Ki Hajar Dewantara, where in learning the teacher must guide students to develop their potential in accordance with the nature and nature of the times (Kemdikbud, 2022). In the independent curriculum, the principle is applied that every student is a unique individual, so a teacher must also be aware of the diversity of his students so that he can provide services that allow all students to have the opportunity to access education effectively according to their needs. This can be realized through differentiation learning.

Differentiated learning is an effort made by the teacher to adjust the learning process in the classroom to meet the learning needs of individual students (Faiz et al., 2022; Kemendikbud, 2020). In addition, Social and Emotional Learning (SEL) is also needed in implementing the independent curriculum.

SEL is learning that is carried out collaboratively by the entire school community where this collaboration process allows children and adults in schools to acquire and apply knowledge, skills and positive attitudes regarding social and emotional aspects in order to understand, live and manage emotions (self-awareness), setting and achieving positive goals (self-management), feeling and showing empathy for others (social awareness). With the application of social and emotional

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learning, it is hoped that a pleasant learning environment will be created so that students enjoy learning (Kemendikbud, 2020).

In phase E of the independent curriculum there is material on the basic laws of chemistry. The material for the basic laws of chemistry is material in the form of a combination of concepts and mathematical calculations, so a high way of thinking and analysis is needed to build and link the given legal concepts. (Lamalat et al., 2018), but the level of cognitive achievement of students is still low (Asfuriyah et al., 2017). In addition, it is known that students still experience misconceptions in the low category (Sa'adah et al., 2022).

The results of observations that were made by distributing questionnaires to students at several schools in West Pasaman showed that 59.3% of students stated that the basic chemical law material was difficult, and 66% said the reason for the basic chemical law material was difficult because there were too many calculations that were difficult to understand. 36.3% said the material was too much, and the rest said the material was too abstract and the teaching materials were not interesting.

The results of interviews with several teachers in West Pasaman chemistry obtained information that the three schools had used the independent curriculum. The teaching materials used by teachers on basic chemical laws are printed books, worksheets, modules, and powerpoints. However, the modules used in observation schools are not yet Problem Based Learning, which is a learning model that is recommended to be used in the independent curriculum.

Based on the problems above and the implementation of an independent curriculum at the senior high school level, it can be an opportunity for educators to develop alternative teaching materials that are valid, practical, and effective in accordance with the latest curriculum standards. One alternative teaching material that can be used is the Module. Module is a book written with the aim that students can study independently without or with teacher guidance (Depdiknas, 2008).

Modules can be modified by adding learning models. One of the learning models suggested in the Independent Curriculum is problem based learning. Learning using the problem base learning model begins by exposing students to real problems. In the process students work and discuss together in teams to solve real problems in the learning process together at school (Ellizar et al., 2019; Musfiqon & Nurdyansyah, 2015b).

The problem base learning learning model initiates students with problems to create meaningful learning (Arends, 2012). Some research results show that module development using the PBL model is valid, practical, effective and can improve students' problem-solving abilities (Asih et al., 2022; Aulia & Hardeli, 2022; Pulungan & Dwi, 2022; Yani et al., 2022).

Providing practicum in the problem base learning model can also add authentic experiences in the learning process. Doing practicum can encourage students to be more active cognitively and psychomotor. Practicum also makes students more active in reviewing existing literature to find concepts. Students who do practicum by applying the PBL model show increased activity in the learning process (Tarigan & Rochintaniawati, 2015). Based on the results of the interviews, it was found that practicum on basic chemical law material is still rarely carried out due to limited tools and materials.

The practicum alternative that can be used is green chemistry oriented. Green chemistry is one of the applications of chemistry to reduce or eliminate environmental problems. Through the integration of the principles of green chemistry, practicum can be designed to be safer to be carried out independently by students by not using hazardous chemicals and prioritizing work safety principles. The results of the research using the principle of green chemistry show that it can increase the activity and independence of students in doing practicum (Kusuma et al., 2021; Ramdhaniah et al., 2021). Practicum implementation can also improve science process skills so that students are able to discover concepts, theories, legal principles and facts (Ikhsan, 2020)(Komisia et al., 2022).

Based on the above problems, the authors are interested in innovating the development of teaching materials that can support the learning process, for this reason the authors submit a research proposal entitled development of a problem based learning integrated green chemistry basic chemical law module to improve science process skills of senior high school students.

Method

This type of research is educational development research (educational design research) or known as EDR. EDR research aims to increase knowledge about the characteristics of educational interventions and the processes used to design and develop a product (Tjeerd Plomp & Nieveen, 2007). The subjects for this research trial were three chemistry lecturers, two chemistry teachers, and students in class X SMAN 2 Pasaman for the 2022/2023 academic year.

The first step in this research is preliminary research. At this stage, a needs analysis, context analysis, literature study, and context framework development were carried out (T. Plomp & N., 2013)) . Needs analysis was carried out by distributing observation questionnaires to teachers and students. At the context analysis stage, an analysis of the curriculum and syllabus was carried out. At the literature study stage, a search for sources and references related to research activities is carried out. At the stage of preparing the conceptual framework, planning, planning, and preparation of the main concepts in the material on the basic laws of chemistry are carried out.

The second stage is the formation of a prototype (prototyping stage). At this stage a module design based on the problem base learning model was prepared based on the results of the analysis at the preliminary research stage accompanied by Tessmer's formative evaluation, namely self-evaluation for prototype I, one-to-one evaluation and expert review for prototype II, small group evaluation for prototype III, and field tests for prototype IV.

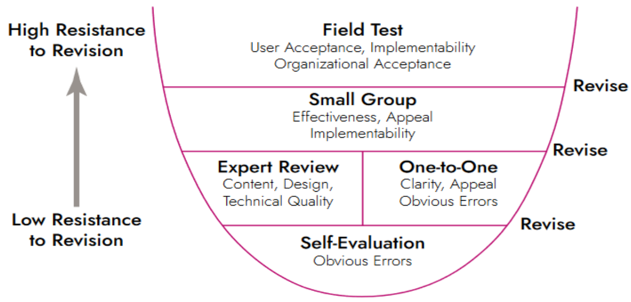

Figure 1. Tessmer's Formative Evaluation Stages (Tjeerd Plomp & Nieveen, 2007)

The instrument used in this study is a validity instrument and a practical instrument in the form of a questionnaire. The data obtained from the product validity test results were analyzed using the Aiken's V formula as shown in the equation below

$$V = \frac{\sum s}{n[c-1]} \quad (1)$$

$$s = r - lo \quad (2)$$

Information:
lo = The lowest score in the category (scoring) (in this case = 1)
c = Number of categories chosen by the rater (in this case = 5)
r = Score given by rater
n = Many raters

The validity criteria are based on the Aiken's V scale as follows (Retnawati, 2016).

Table 1. Aiken's V Scale Validity Assessment Criteria

Aiken's V Scale	Validity
$V \leq 0.4$	Less
$0.4 < V \leq 0.8$	Medium
$0.8 < V$	Valid

The data generated from the practicality test were analyzed using the following equation.

$$P = \frac{Q}{R} x\ 100\% \quad (3)$$

Information:
P = Practicality value
Q = Score obtained
R = Highest score

The level of practicality of the developed e-module can be seen in Table 2 (Riduwan, 2008).

Table 2. Practicality Assessment Criteria

Value (%)	Criteria
$80 < x \leq 100$	Very Practical
$60 < x \leq 80$	Practical
$40 < x \leq 60$	Quite Practical
$20 < x \leq 40$	Less Practical
$0 < x \leq 20$	Impractical

The field trial design used was a quasi-experimental design (Sugiono, 2012) and the sampling technique used was purposive sampling, where the sample was determined based on certain considerations. The research design is described as follows (Table 3)

Table 3. Research Design

Class	Pretest	Treatment	Postest
Experiment	T_1	X	T_2
Control	T_3		T_4

At the end of learning the two sample classes were given a test. The test given is in the form of an objective test of 10 items and an essay test of 10 items. The final test questions used are questions that have been tested and analyzed, so that they meet the criteria of a good item, namely valid, reliable, have differentiating power and question difficulty index.

To see the effectiveness of using the learning module, the t-test is used, but before the t-test, an analysis prerequisite test must be carried out using normality and homogeneity tests. If the requirements are fulfilled that the sample comes from a population with normal distribution and homogeneity, then a t-test is then carried out with a significance level of 5%.

Result and Discussion

Preliminary Research

To determine whether or not the media actually needs to be created, this examination is required. Chemistry teachers were questioned for needs assessments, and students completed packages. Interviewing instructors and students is done to learn more about the topics they cover in class and the challenges they experience.

According to the results of the interviews, the teacher used printed books, worksheets, modules, and powerpoints to teach basic chemical law, but not for the practicum. Although it is acknowledged that textbooks don't cover everything in great detail, they can't fully develop students' thoughts and conceptions (Elbaz, 2018).

Based on the results of the questionnaire given to students in three schools, the students stated that the material on basic chemical laws was difficult. The material for the basic laws of chemistry is material in the form of a combination of concepts and mathematical calculations, so a high way of thinking and analysis is needed to build and link the given legal concepts (Lamalat et al., 2018).

The learning outcomes of the students in the autonomous curriculum were examined using context analysis. Students' ability to observe, explore, and explain facts in accordance with scientific work principles when describing chemical concepts in daily life is one of the learning goals in the area of fundamental chemical laws.

Literature research comes next. The purpose of this phase is to locate references relevant to the upcoming research. Trustworthy journal articles, novels, periodicals, and websites are all acceptable forms of the literature. The module's components were created with the base learning problem's syntax in mind (Arends, 2012), material for the basic laws of chemistry is taken from university books adapted to the level of high school students.

Concept analysis is the final step. This analysis seeks to identify the elements required to identify the fundamental ideas of the relevant chemical laws. The analysis's findings indicate that the rules of mass conservation, fixed proportions, numerous proportions, and volume ratios are the fundamental ideas of chemistry's fundamental laws.

Prototyping Phase

The creation of the introduction led to the creation of prototype I. The final product is a fundamental chemical laws module that combines green chemistry and problem-based learning. Figure 1 shows the display of the module cover.

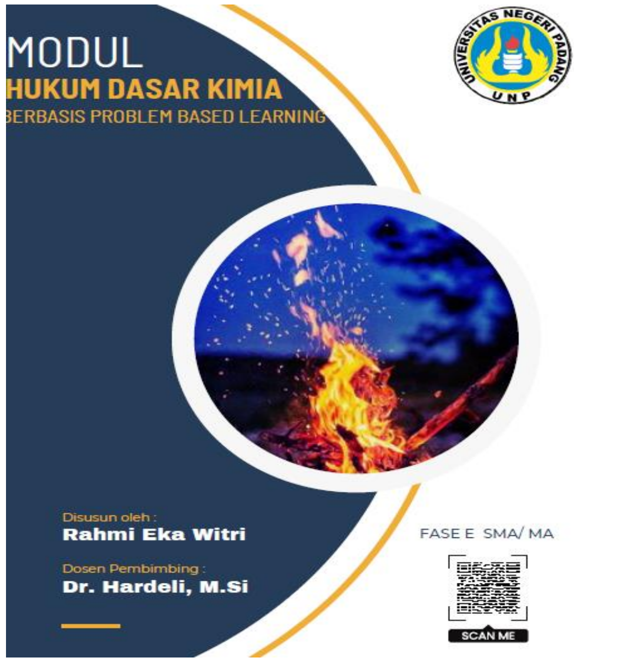

Figure 2. Module Cover

The assignments that students must complete are listed on the activity sheet. The format of this activity sheet is based on the syntax used in the problem-based learning model. Students must first be introduced to the issue. The goal of the problem orientation stage is to guide pupils toward the problem that serves as the subject of their learning.

Figure 3. Problem Orientation Stage Display

The second level is where learning activities are organized. At this point, students are required to engage in group discussions about the issues raised during the problem orientation stage. Leading individual or group investigations is the third stage. It now includes practical activity manuals, video examples, and questions that direct students in gathering data in order to address the challenges raised.

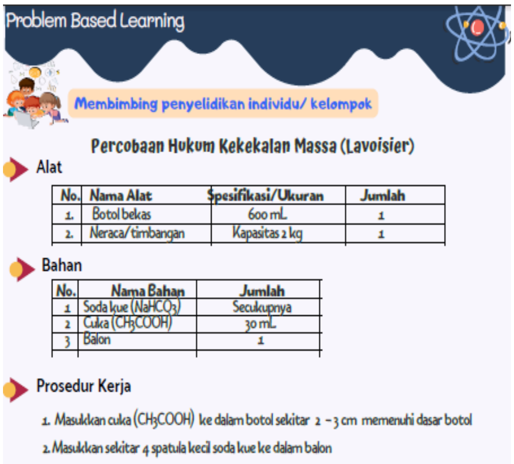

Figure 4. Stage of Guiding Independent and Group Investigations

Presenting and developing the work is the fourth step. At this point, students are expected to write reports on discussions and problem-solving outcomes and develop presentations using ppt, infographics, videos, concept maps, or posters depending on their individual skills and interests. These presentations are then made in class.

The study and evaluation of the problem-solving process is the last step. The outcomes of the supplied conversations and problem-solving are now assessed and analyzed, and any critiques and ideas are noted in the provided column.

After receiving prototype I, prototype II was created by self-evaluation. This self-evaluation concentrates on obvious errors like incompatible letter typing, the usage of graphics, module completion, such as items that must belong to the module, and the accuracy of the stages of the problem-based learning model. The assessment answer key was added to the program, and there have generally been significant improvements to the writing errors and letter size.

After prototype II underwent individual (one-on-one) examination and expert review, prototype III was produced. To create prototypes that are scientifically legitimate, expert evaluation is done on the graphics, language, and construct of the prototypes. The outcomes of the applied construct validation may be shown in Table 4.

Table 4. Construct Validation Analysis

Rated Aspect	Aiken's V	Category
Content	0.92	Valid
Language	0.88	Valid
Serving	0.89	Valid
Graphic	0.91	Valid
The average value of V	0.90	Valid

The average value of Aiken's V suggests that the problem-based learning-based chemical law module designed is in accordance with the learning objectives to be attained and that the offered content is in accordance with students' abilities. This supports the idea that a product's content validity shows it was developed in conformity with the curriculum and has a solid theoretical foundation (Lubis et al., 2022; Rochmad, 2012). A learning medium satisfies content validity when all of its created components are backed by theories that are both comprehensive and mutually supportive of the learning objectives (Tjeerd Plomp & Nieveen, 2007).

Furthermore, the content validity assessment showed that the basic chemical law module had an Aiken's V value of 0.91. The results of e-module content validation can be seen in Table 5.

Table 5. Module Content Validation Analysis

Rated Aspect	Aiken's V	Category
Suitability of the contents of the module with the syntax of Problem Based Learning	0.90	Valid
The suitability of the contents of the module to the chemical scientific content	0.92	Valid
The average value of V	0.91	Valid

The problem-based learning learning model encourages pupils to learn by posing real-world situations. Students are divided into small groups and work cooperatively to address problems that arise in the real world as part of the PBL learning approach in the classroom (Musfiqon & Nurdyansyah, 2015a).

Based on the results of the one-on-one evaluation questionnaire on the basic chemistry law module based on problem-based learning integrated with green chemistry, it was determined that the cover of the module looks appealing because it is simple, elegant, and comes with supporting images that pique students' interest in reading it. The module's beautiful color scheme and overall aesthetic make students feel at ease and prevent them from getting easily bored while reading it. The letters used in modules are clearly sized and readable, which is relevant to the use of letters in modules.

Prototype IV was obtained after conducting a small group evaluation of prototype III. The purpose of the small group evaluation is to test the practicality of the developed module before it is used in a large group test. The analysis at the small group evaluation stage can be seen in Table 6.

Table 6. Small Group Test Results

Rated Aspect	Value	Category
Ease of use	0.86	Very Practical
Study time efficiency	0.88	Very Practical
Benefit	0.82	Very Practical
Average value	0.85	Very Practical

The data obtained shows that the module in the form of prototype IV is practical to use. The practicality of the resulting inner module is then tested on a large scale

Assessment Phase

The assessment phase seeks to ascertain the applicability and efficacy of the modules that are field tested on sizable groups. The assessment phase aims to determine the practicality and effectiveness of the module being tested on a large group.

The findings of (1) the student's evaluation of the developed module and (2) the teacher's response to the developed module are used to determine the developed module's practicality. Table 7 displays the findings of the investigation of the module practicality data.

Table 7. Module Practical Test Results on Field Test

Rated Aspect	Teacher	Students	Category
Ease of use	0.89	0.85	Very Practical
Study time efficiency	0.87	0.81	Very Practical
Benefit	0.87	0.84	Very Practical
Average value	0.88	0.84	Very Practical

The results of the practicality test on the module's ease of use component are in the very practical category. This provides information that the component of using the module can be used in terms of clear learning instructions, the material displayed is simple, the learning stages in the module can be carried out properly.

The results of the practicality test of the efficiency and learning time components are in the very practical category. Based on these data it can be concluded that the use of modules helps in learning because of instructions the use of modules is easy to understand, the materials, pictures and videos are clear, the writing used is clear and easy to read. The results of the practicality test of the module benefit components are in the very practical category, this indicates that the use of the module can increase students' understanding and activeness in learning

The created modules can serve as a catalyst and assist students in carrying out learning tasks in order to master a knowledge, talent, or attitude. Additionally, the module's use of worksheets can help focus instruction for increased effectiveness and efficiency (Efliana et al., 2022; Majid & Rochman, 2014).

Regarding the advantages for teachers, the modules created can track and evaluate group student performance as well as gather knowledge regarding understanding through participation in the learning process by students. While the advantages for pupils include a rise in interest, particularly the ability to interact, communicate with one another, boost creativity, and develop critical thinking abilities. And maybe most importantly, it can assist students in finding solutions to issues pertaining to the subject (Syafira & Effendi, 2020).

The results of the N-gain score in the field test at SMAN 2 Pasaman show that the N-gain score of the experimental class is higher than the control class as shown in Table 8.

Table 8. Average N-Gain Score in the Field Test

Class	N	*Pretest* Average	*Posttest* Average	*N-Gain* Average	Criteria
Experiment	30	8.40	85.02	0.84	High
Control	30	6.20	78.54	0.77	High

From the data it can be seen that the N-Gain value for the experimental class is higher than the control class, this shows the difference before and after the treatment is given. To find out whether the module has an effect on student learning outcomes, it is necessary to test the hypothesis.

Based on the results of hypothesis testing obtained $t_h > t_t$, these data indicate that the cognitive learning outcomes of students in the experimental class are significantly higher than the control class, meaning that the use of problem base learning based on chemical laws module is effective on student learning outcomes.

Table 9. Results of Hypothesis Testing on Cognitive Learning Outcomes of the Sampe class

Class	N	α	T_{count}	t_{table}
Experiment	30	0.05	2.8727	1.67155
Control	30			

Problem-based learning using modules can improve understanding of material, improve students' ability to work together, develop ideas, respect the opinions of others, interact with friends and teachers, solve a problem and improve learning outcomes. PBL learning that is integrated with the chemistry module is considered quite effective in increasing students' cognitive, affective and achievement motivation (Kusumah et al., 2020; Yani et al., 2022).

Problem-based learning has three objectives, namely: (1) increasing the ability to solve problems, (2) increasing the independent work of each individual, and

(3) producing meaningful learning. Learning using problem based learning can improve communication, negotiation, collaboration, independence, self-confidence, dare to make decisions and improve group work skills (Nowrouzian & Farewell, 2013).

Modules that are integrated with the green chemistry practicum form the character of students to have a sense of care for the environment so that they play a role in maintaining the environment (Kimianti et al., 2016). The concept of green chemistry has 12 principles that serve as a guide for the application of green chemistry in real action. Some of the principles of green chemistry that are applied in the module are the use of safe solvents and materials, the use of renewable raw materials, and the prevention of air pollution (Anastas & Eghbali, 2010).

The results of the analysis of the Science Process Skills indicators for the control and experimental classes can be seen in Table 10. Based on Table 10 it is known that the N-Gain value of each indicator of science process skills in the experimental class is greater than that of the control class. This shows that the science process skills of students who use problem-based learning integrated green chemistry-based basic chemical law modules are significantly higher than the class without using problem-based learning integrated green chemistry-based basic chemical law modules.

Table 10. Results of N Gain Value of Science Process Capability Indicators

Indicator	Class	
	Control	Experiment
Observation	0.72	0.73
Inference	0.68	0.72
Classification	0.89	0.92
Interpret/Predict	0.68	0.76
Communication	0.82	0.95

The module as a tool can be used to improve students' science process skills in learning. Modules can guide students to think logically, critically, and systematically because students are required to find information on their own in learning and can be used to help foster student creativity in order to be able to answer a problem, so that in learning students actively seek and find answers to problems themselves while the teacher is only a motivator and facilitator (Bybee, 2014; Oktaviani et al., 2015; Sakinah et al., 2018).

Conclusion

Through Educational Design Research and a plomp development approach, a basic chemical law module based on green chemistry has been created that is integrated with learning problems. With a valid category for construct validity and a valid category for content validity, the construct validity results were 0.90 and 0.91, respectively. The practicality scores of teachers and students are included in the very practical group with respective values of 0.88 and 0.84. The results of the t test on student learning outcomes showed that $t_h > t_t$, and the value of science process skills in the experimental class was higher than the control class. Therefore, it can be said that the module based on problem base learning integrated with green chemistry on basic chemical law material is valid, practicable, and effective. The effectiveness of the module is seen from the learning outcomes and science process skills, so that this module is appropriate for use in the learning process.

Author Contribution

Rahmi Eka Witri: preparation of the original manuscript, results, discussion, methodology, conclusions; perform analysis, proofreading, review, and editing; Hardeli: validation, review and supervision; Desy Kurniawati and Yerimadesi: validating

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper

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