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Development and Effectiveness of a Canva-Based Problem-Based Learning E-Module Using the 4D Model to Improve Students' Understanding of Molecular Shapes

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Abstract
This study aims to develop and evaluate the effectiveness of a Canva-based e-module using the Problem-Based Learning (PBL) approach to improve students' understanding of molecular shapes. The research employed a Research and Development (R&D) method using the 4D model (define, design, develop, disseminate). The effectiveness test applied a one-group pretest–posttest design involving 35 tenth-grade students at SMA Negeri 2 Medan selected through purposive sampling. The research instrument consisted of a multiple-choice test that was validated and tested for reliability (KR-20 = 0.811). Data analysis techniques included normality test, paired sample t-test, and N-gain analysis. The validation results showed that the e-module was highly feasible, with scores of 90.56% from media experts and 89.38% from material experts. The paired t-test results indicated a significant difference between pretest and posttest scores ($p < 0.05$), supported by an N-gain value of 0.76 (high category). These findings indicate that the Canva-based PBL e-module is both feasible and statistically effective in improving students' understanding of molecular shapes.

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INTRODUCTION

Education represents a systematic and essential process in shaping students' character and personal development. In today's digital age, the role of education becomes increasingly significant as it contributes directly to the advancement and competitiveness of a nation. The enhancement of educational quality is widely recognized as a critical element that supports national progress and sustainable development (Makkawaru, 2019). In line with this perspective, Law No. 20 of 2003 on the National Education System states that education is a deliberate and well-planned effort designed to create learning environments that allow learners to actively develop their potential. This development includes strengthening spiritual values, self-discipline, personality formation, moral integrity, and the acquisition of competen-cies required for personal life, social interaction, and national development (Budiarti et al., 2017).

Currently, the education system in Indonesia has begun to adopt the Merdeka Curriculum, although its implementation has not yet been evenly applied in all schools (Zakso, 2022). This curriculum emphasizes the integration of technology in learning, considering the rapid development of the digital era in the Industrial Revolution 5.0. The Merdeka Curriculum promotes student-centered learning rather than teacher-centered learning. However, in practice, many teachers have not fully implemented this approach. Learning activities are often conducted without the support of teaching modules or student worksheets, which limits opportunities for students to develop their learning abilities independently.

Education plays a crucial role in developing students' competencies in the 21st century. The implementation of the Merdeka Curriculum emphasizes student-centered learning and the integration of technology. However, chemistry learning still faces challenges, especially in abstract topics such as molecular shapes, which require visualization skills. In order to effectively implement this curriculum, learning strategies are needed that can actively involve students while fostering cooperation, participation, and higher-order thinking abilities. An instructional strategy that aligns with these principles is Problem Based Learning (PBL). This approach emphasizes student-centered learning by actively involving learners in examining real-life problems and seeking appropriate solutions. Through this process, students are encouraged to think critically, collaborate with peers, and construct their own understanding of the subject matter. A number of prior studies have indicated that integrating PBL within the implementation of the Merdeka Curriculum can significantly increase student engagement in classroom activities. Several previous studies have reported that the use of PBL within the Merdeka Curriculum framework can enhance student participation and improve learning achievement by providing learning experiences that are more meaningful and relevant (Mastuti, 2024).

Chemistry is frequently perceived by students as a challenging subject because it involves many concepts that cannot be directly observed. The study of chemistry aims to help learners comprehend fundamental chemical principles and recognize their relevance in daily life as well as in technological developments (Febriani et al., 2024). One of the key topics in this field is chemical bonding, which explains how atoms interact and connect to form stable compounds. Because these interactions occur at the microscopic level and are not visible to the naked eye, the concept of chemical bonding is often regarded as difficult for students to fully understand (Silaban et al., 2020).

Instructional media plays an important role in helping learners grasp concepts that are difficult to visualize and also encourages students to study more independently. One type of instructional material that is widely applied in the learning process is the learning module. In line with technological advancements, these modules have evolved into electronic modules or e-modules, which are learning materials delivered in digital format and can be accessed through electronic devices such as smartphones, laptops, or computers (Azizah & Ardhana, 2023). Compared to conventional printed modules, e-modules allow the integration of various multimedia components, including instructional videos, interactive activities, digital presentations, and flipbook features, which can make the learning experience more dynamic and interesting (Widiantari et al., 2022). Furthermore, digital modules are considered more efficient and flexible because they minimize the use of printed resources and enable students to access learning materials anytime and from any location.

Research conducted by Simangunsong & Purba (2025) revealed that an electronic module on thermochemistry developed through the Canva platform produced learning media with excellent quality. The study showed that the e-module met very high standards in terms of both validity and practicality, indicating that it is highly suitable to support the teaching and learning process in the classroom. The validation results indicated material feasibility of 91.8% and media feasibility of 90.8%, both categorized as "highly valid." Student responses also showed a positive result of 90.1%, indicating that Canva-based e-modules are more attractive, easy to understand, and helpful in learning through visually appealing displays and simple navigation. Similarly, research by Putri et al. (2023) reported that Canva-based e-modules were highly feasible, receiving validation scores of 88.63% from material experts, 88.3% from media experts, and 100% from language experts, with a student response rate of 86.21%.

A study by Siregar & Harahap (2020) focused on designing an electronic learning module based on the Project Based Learning (PjBL) approach for the topic of molecular geometry. The module incorporated HyperChem simulation software to enable students to observe and explore molecular structures in a three-dimensional form. The results of the research demonstrated that the digital module that had been developed fulfilled high criteria of feasibility and proved effective in improving students' understanding of concepts. In addition, the use of the module was able to stimulate greater student involvement and foster stronger interest during the learning activities. In

addition, Silaban (2021) found that chemical bonding e-modules equipped with images and structured explanations were effective in improving students' conceptual understanding compared to conventional teaching materials.

Based on preliminary observations at SMA Negeri 2 Medan, the learning process is still dominated by teacher-centered methods. Teachers generally rely on textbooks when explaining chemical bonding material. Students reported that lecture-based learning tends to be monotonous and decreases their interest in learning, especially because chemistry classes are often conducted in the afternoon. For that reason, the learning process requires the integration of creative and innovative instructional media that can stimulate students' interest while helping them better comprehend complex and abstract chemistry concepts.

Based on interviews conducted with a chemistry teacher at SMA Negeri 2 Medan, it was found that the utilization of digital learning media in chemistry classes is still relatively minimal. Students frequently encounter challenges when studying chemical bonding, especially in understanding the concept of molecular geometry. This difficulty is also reflected in the relatively low scores obtained by students on assignments related to this topic. Therefore, the incorporation of digital learning media is considered necessary to create a learning process that is more flexible, engaging, and effective.

However, previous studies have mainly focused on the feasibility and student responses toward Canva-based e-modules. Limited studies have examined the effectiveness of Canva-based Problem-Based Learning e-modules on molecular shape concepts using a structured 4D development model supported by rigorous statistical analysis.Therefore, this study aims to fill this gap by developing and testing the effectiveness of a Canva-based PBL e-module using the 4D model combined with inferential statistical analysis.

Considering these conditions, the researcher aims to develop an instructional medium entitled "Development of a Problem Based Learning (PBL)-Based E-Module Using Canva on Chemical Bonding." The development of this e-module is expected to serve as an innovative learning resource that can support the teaching and learning process while helping to enhance students' comprehension and academic performance in chemistry.

METHOD

This study employed a Research and Development (R&D) approach using the 4D model, which consists of define, design, develop, and disseminate stages. To evaluate the effectiveness of the developed e-module, a one-group pretest–posttest design was applied. The study involved 35 class x students selected using a purposive sampling technique. The main objective of the research was to explore the challenges encountered by students when studying molecular structure concepts and to assess the demand for the integration of digital learning resources in the chemistry learning process.

The data used in this research were collected using various methods, namely interviews with teachers, distribution of questionnaires to students, analysis of relevant documentation, and examination of students' assignment or task scores. The interview with the chemistry teacher was conducted to gain deeper insights into the current learning practices, instructional methods used in the classroom, and the extent to which learning media have been utilized during chemistry instruction. The research instrument consisted of a multiple-choice test, which was validated using product-moment correlation and tested for reliability using the KR-20 formula. Questionnaires were distributed to 35 students to identify their learning difficulties and their preferences for learning media. Documentation studies were carried out by reviewing curriculum documents and learning objectives, while students' assignment scores were analyzed to determine their academic ability levels in molecular structure material.

The needs analysis phase was conducted through four key stages: a preliminary analysis, an analysis of students' needs, a task analysis, and an analysis of the intended learning objectives. The initial analysis was conducted by interviewing the teacher to identify challenges encountered during the learning process and to examine the curriculum applied in the school. Student needs analysis was conducted through questionnaires to determine students' difficulties and their interest in digital learning media. Task analysis examined students' assignment scores to

determine their academic ability levels, while objective analysis was conducted by reviewing the learning objectives and curriculum documents. The collected data were analyzed using descriptive analysis techniques and percentage calculations to describe students' needs and learning conditions as the basis for developing the PBL-based e-module.

RESULTS AND DISCUSSION

Results

This research was carried out at SMA Negeri 2 Medan in January 2026 with the participation of 35 students from class X-6. The study focused on developing an electronic learning module based on the Problem Based Learning (PBL) approach using the Canva platform for the topic of molecular structure. The development process followed the 4D model, which consists of four stages: Define, Design, Develop, and Disseminate.

Define

The define stage aimed to analyze learning conditions, student characteristics, and learning needs. Based on interviews with chemistry teachers, it was found that many students struggled to comprehend the abstract concepts related to molecular shapes. In addition, the learning process was still predominantly teacher-centered, with instruction mainly relying on textbooks and student worksheets. A needs analysis involving 35 students also revealed limited learning resources and students' preference for digital learning media. Task analysis based on assignment scores showed varying academic abilities among students as displayed in Table 1.

Table 1. Student Ability on Assignment

Ability Category	Score Range	Number of Students	Percentage
Low	< 60	19	54%
Medium	61-75	11	31%
High	> 75	5	14%

Curriculum analysis showed that the school applies the Merdeka Curriculum, and the learning objectives focused on determining molecular shapes using VSEPR theory and electron domain theory.

Design

During the design phase, the main activity involved determining and organizing the overall layout, structure, and format of the e-module to be developed. Based on the analysis results, e-modules were selected as learning media because they can integrate text, images, and visual illustrations to support understanding of abstract concepts. The module was designed using Canva and consisted of three main sections: introduction (cover, concept map, instructions, learning objectives), learning activities based on Problem Based Learning syntax, and closing sections including summary, reflection, assignments, glossary, and references.

Figure 1. Preview of E-Module

Development

During the development phase, the e-module that had been designed was evaluated by experts in order to assess its feasibility prior to being applied in the classroom setting. The validation process involved two chemistry lecturers from Universitas Negeri Medan and one chemistry teacher. The media validation results are summarized in Table 2.

Table 2. Media Expert Validation Results

Aspect	Percentage(%)	Category
Visual Design Quality	88.33	Very Feasible
Functionality and System Performance	95.00	Very Feasible
Learning Integration	88.33	Very Feasible
Average	**90.56**	**Very Feasible**

As shown in Table 2, the developed e-module obtained an average feasibility score of 90.56%, which falls into the "very feasible" category. The highest score was obtained in the functionality and system performance aspect (95%), indicating that the navigation features and system functions of the e-module operate effectively and are easy for users to access. Meanwhile, the visual design quality and learning integration aspects also received high scores, demonstrating that the visual appearance of the e-module is attractive

and that the learning content is well aligned with instructional objectives.

In addition to media validation, the content of the e-module was also evaluated by subject matter experts. The results of the material validation are presented in Table 3.

Table 3. Material Expert Validation Results

Aspect	Percentage (%)	Category
Content Feasibility	89.81	Very Feasible
Presentation Feasibility	91.67	Very Feasible
Language Feasibility	86.67	Very Feasible
Average	**89.38**	**Very Feasible**

Based on Table 3, the overall average score obtained from the material expert validation is 89.38%, which also falls into the very feasible category. This result indicates that the content of the developed e-module is considered appropriate and suitable for use in the learning process.

In addition to the validation of the learning media and content, the learning test instrument used in this study was also analyzed to ensure its validity and reliability. The test instrument consisted of 35 multiple-choice questions designed to measure students' understanding of the molecular shape topic after using the developed e-module.

The results of the item validity test showed that 27 questions were declared valid, while 8 questions were categorized as invalid and therefore not used in the final analysis. Furthermore, the reliability of the instrument was tested using the Kuder–Richardson (KR-20) formula. The reliability analysis produced a value of $r_{11} = 0.811$, which is higher than the rtable value of 0.334, indicating that the instrument has a high level of reliability and can be consistently used to measure students' learning outcomes.

In addition, the difficulty level analysis of the test items revealed that the instrument contained 2 difficult questions, 29 moderate questions, and 4 easy questions. This distribution indicates that the test items are generally balanced and appropriate for evaluating students' understanding, as most of the questions fall into the moderate difficulty category. A balanced level of difficulty is important in assessment instruments because it allows for a more accurate measurement of students' learning achievement and conceptual understanding.

Disseminate

The dissemination phase constituted the final step of the development procedure. At this stage, the completed e-module was implemented and tried out with students to examine its effectiveness. The objective of this stage was to evaluate whether the Problem Based Learning (PBL) e-module created using Canva could improve students' learning outcomes on the topic of molecular shapes. The trial implementation was carried out on a limited basis with the participation of 35 students.

To assess the improvement in learning, students completed a pretest before the instructional activities and a posttest after learning with the developed e-module. The comparison of the pretest and posttest results was then used to determine the effectiveness of the e-module. The summary of the pretest and posttest analysis results is presented in Table 4.

Table 4. Pretest and Posttest Results

Test	Mean Score	N-gain	Category
Pre-Test	39.00	0.76	High
Pos-test	84.86		

As shown in Table 4, the average pretest score was 39.00, indicating that students' initial understanding of molecular shape material was still relatively low. After learning using the developed e-module, the average posttest score increased to 84.86. The calculated N-gain value of 0.76 falls into the high category, indicating that the e-module effectively improved students' learning outcomes.

The normality test results showed that the data were normally distributed ($p > 0.05$). Therefore, a paired sample t-test was conducted. The results indicated a significant difference between pretest and posttest scores ($p < 0.05$), confirming that the use of the e-module significantly improved students' learning outcomes.

To further examine the level of improvement, the distribution of students' N-gain scores was also analyzed. The results are presented in Table 5. Most students achieved a high N-gain category, with 68.57% of students showing significant improvement in their learn-ing outcomes, while 31.42% were in the medium category. No students were categorized in the low

category, indicating that the e-module contributed positively to students' understanding.

Table 5. Distribution of Student N-Gain Scores

Category	Criteria	Number of Students	Percentage
High	$g \geq 0.70$	24	68.57%
Medium	$0.30 \leq g < 0.69$	11	31.42%
Low	$g < 0.30$	0	0%

In addition to learning outcomes, students' responses toward the developed e-module were also evaluated through a questionnaire. The results of the student response analysis are shown in Table 6.

Table 6. Student Responses to the E- Module

Aspect	Percentage (%)	Category
Attractiveness	85.29	Very Positive
Usability	85.00	Very Positive
Effectiveness	85.71	Very Positive
Average	85.71	Very Positive

The data shown in Table 6 demonstrate that students gave highly positive responses to the implementation of the developed e-module. They perceived the e-module as visually appealing, user-friendly, and helpful in facilitating their understanding of molecular shape concepts. In general, these results suggest that the Canva-based e-module developed using the Problem Based Learning (PBL) approach is appropriate for use in learning, effective in supporting comprehension, and positively received by students.

Initial Needs Analysis for the Development of a Problem Based Learning E-Module Using Canva

The preliminary needs assessment was carried out to examine the challenges encountered in the learning process and to evaluate the necessity of developing a Canva-based e-module utilizing the Problem Based Learning (PBL) approach. This assessment involved several stages, including initial analysis, curriculum review, analysis of student needs, task analysis, and the learning objectives formulation.

Interviews with a chemistry teacher at SMA Negeri 2 Medan revealed that students still experience difficulties in understanding abstract chemistry concepts, particularly molecular shapes. This topic requires students to visualize the three-dimensional arrangement of atoms and understand the relationship between bonding and lone electron pairs that determine molecular geometry. Because these concepts cannot be directly observed, students require learning media that provide clearer visual representations.

In addition, learning activities are still dominated by teacher-centered methods and rely mainly on textbooks and worksheets. The results of the student questionnaire also showed that many students find molecular shape material difficult and need more interactive learning resources with clear visual illustrations. These findings indicate the importance of developing digital learning media that can support active learning and improve conceptual visualization.

The development of a PBL-based e-module using Canva is therefore considered appropriate because it allows students to engage in problem-solving activities while accessing visual representations of molecular structures. Similar findings were reported by Sari & Kurniawati (2022), who stated that PBL-based e-modules improve conceptual understanding through active problem analysis, and Pratiwi et al. (2023), who found that integrating problem-based learning with digital media increases student engagement and critical thinking skills.

Feasibility of the Problem Based Learning E-Module Based on BSNP Standards

The feasibility of the developed e-module was evaluated through expert evaluation from both media and material validators to determine whether it met BSNP standards and was suitable for chemistry learning.

Media expert validation results showed a feasibility score of 90.56%, categorized as very feasible. The highest score was obtained in the functionality and system performance aspect (95%), indicating that the navigation and features of the e-module function effectively and are easy for students to use. Meanwhile, the visual design quality and learning integration aspects obtained 88.33%, showing that the module demonstrates an engaging design with clearly organized instructional content.

Material expert validation also showed a very feasible result with an average score of 89.38%, with the highest score in the presentation aspect (91.67%), indicating that the material is presented systematically and logically. These findings are consistent with Putri & Lestari (2022), who reported that digital modules with clear navigation and appealing visual layouts tend to obtain high feasibility ratings. Similarly, Rahma-

wati et al. (2023) found that Problem Based Learning chemistry e-modules achieve very feasible validation results because the materials support structured and active learning.

The Effectiveness of the Problem Based Learning E-Module in Enhancing Students' Learning Outcomes and Student Responses

The effectiveness of the developed e-module was analyzed through pretest, posttest, and N-gain calculations. The results showed that the average pretest score was 39.00, which was below the minimum mastery criterion (KKM = 75), indicating low initial understanding of the molecular shape material. After the learning process using the developed e-module, the average posttest score increased to 84.86, exceeding the KKM.

The calculated N-gain value of 0.76 falls within the high category, indicating a notable improvement in students' academic performance. An analysis of the N-gain distribution revealed that the majority of students (68.57%) achieved scores in the high improvement category, while 31.42% were categorized in the moderate level. No students were found to be in the low improvement category. This result indicates that the PBL-based e-module effectively supports students in understanding molecular shape concepts through problem-solving activities and active learning processes.

The effectiveness of the PBL-based e-module can be explained through constructivist learning theory, where students actively construct knowledge through problem-solving activities (Piaget; Vygotsky).In addition, the integration of Canva-based visual elements supports the Cognitive Theory of Multimedia Learning (Mayer), which states that combining visual and verbal information enhances understanding, especially for abstract concepts such as molecular shapes. Furthermore, visualization plays a crucial role in chemistry learning, as it helps students understand microscopic representations that cannot be observed directly.

Student responses toward the developed e-module were also very positive, with an average score of 85.71%, categorized as very positive. Students reported that the e-module was attractive, easy to use, and helped them understand the material more effectively. These findings are consistent with Suryani & Wulandari (2022), who reported significant learning improvement after implementing PBL-based e-modules, as well as Aladin et al. (2024) and Wahyuni & Fitriani (2023), who found that interactive digital modules increase student engagement, motivation, and independent learning.

CONCLUSION

The Canva-based PBL e-module developed using the 4D model is highly feasible based on expert validation. The findings demonstrate that the developed e-module fulfills the established feasibility criteria and can be effectively utilized as a digital instructional resource in senior high school chemistry learning. Based on expert validation, the developed e-module fulfills the criteria of feasible instructional media according to BSNP standards, demonstrating appropriate content organization, clear presentation, and effective visual design. These characteristics support the integration of problem-based learning activities that encourage students to actively analyze problems and construct conceptual understanding. The e-module is statistically effective in improving students' understanding of molecular shapes, as indicated by paired t-test results ($p < 0.05$) and a high N-gain score. Furthermore, the implementation of the e-module in classroom learning shows that the use of a PBL-based digital module contributes to improving students' understanding of molecular shape concepts. The learning approach embedded in the module facilitates active learning, problem-solving, and conceptual visualization, which are essential for mastering abstract chemistry topics. Overall, the findings confirm that the PBL-based Canva e-module is a feasible and effective learning medium that can support more interactive, student-centered, and meaningful chemistry learning, particularly in helping students understand complex and abstract concepts such as molecular shapes.

RECOMMENDATION

Based on the findings of this study, chemistry teachers are recommended to implement Canva-based e-modules integrated with the Problem-Based Learning (PBL) approach as an alternative digital learning resource, particularly for teaching abstract topics such as chemical bonding and molecular geometry. The use of such e-modules can facilitate students' conceptual understanding

through structured problem-solving activities and visual representations.

Schools are encouraged to provide adequate technological infrastructure and professional development programs to support teachers in designing and implementing interactive digital learning media effectively.

For future research, it is strongly recommended to conduct experimental studies using a control group design in order to obtain more rigorous evidence regarding the effectiveness of Canva-based PBL e-modules. Additionally, future studies should explore the integration of advanced technologies, such as Augmented Reality (AR) or 3D molecular visualization, to further enhance students' understanding of abstract chemistry concepts.

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