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Development of Project-Based Learning-Based Learner Activity Sheet to Improve Creative Thinking Skills on Chemical Bonding

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Abstract: This study aims to design and produce a Project-Based Learning (PjBL) oriented Learner Activity Sheet (LAS) to foster creative thinking abilities among learners in the context of chemical bonding. The study involved 31 students of class XI MIPA at SMAS Barunawati Surabaya. The study employed the 4D development model (Define, Design, Development, and Dissemination), but was limited to the Development stage. Several instruments were employed, including a media validation sheet, learner response questionnaire, observation data of learner activities and learning implementation, as well as tests for creative thinking skills and learning outcomes. The PjBL-based LAS for chemical bonding was evaluated for its feasibility and declared valid by three validators in terms of content and construct. It was also found to be practical based on positive student feedback and 'very good' ratings for student activity and learning implementation. Furthermore, the tool proved effective, demonstrated by significant improvements in students' creative thinking skills and cognitive learning outcomes. In conclusion, the developed Project-Based Learning LAS for chemical bonding fulfills the quality criteria of a teaching material in terms of validity, practicality, and effectiveness.

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Introduction

Human civilization has always undergone development from time to time. In the European Region, societal transformation began from the industrial revolution 1.0 to reaching the industrial revolution 5.0, also known as the 21st century society (Heri et al., 2021). In the 21st century, there are four main skills that students need to have. This skill is known as the "Four Cs", which includes the ability to think *critically*, communicate effectively, work in a team (*collaboration*), and create new things creatively (Roekel, 2010). In addition to these four aspects, *The Partnership for 21st Century Skills* also emphasizes the importance of mastering other skills such as awareness of global issues, innovation skills, problem-solving skills, and information literacy. Thus, students in this era are expected to have the ability to compete at the global level, both in terms of knowledge and skills (Redhana, 2019).

Indonesia has been trying to improve its quality of life in various aspects of the 21st century, especially in the education and social sectors. These two are closely related, as good education is considered the basis for creating a prosperous social life. The government imposed an independent curriculum policy (Cahyani et al., 2022). The Merdeka Belajar curriculum aims to improve education quality in Indonesia by developing students' character and competence through flexible, student-centered learning. It emphasizes independent learning, teacher autonomy, and character building based on the Pancasila learner profile, including creativity, critical thinking, and global awareness. (Ningrum, 2022).

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Creative thinking skills are an individual's ability to generate new approaches, strategies, ideas, or ideas as alternative solutions to a problem. This ability plays an important role in supporting the problem solving process effectively (Putri & Alberida, 2022). The ability to think creatively is vital for individuals, as it enables them to approach challenges from various perspectives and effectively adapt to the complexities of their social environment. According to Hidayah et al. (2021), creative thinking can be identified through four main indicators, namely: (1) fluency, which is the ability to produce various alternative answers to a question; (2) flexibility, which is the ability to interpret a picture, story, or problem from various perspectives; (3) elaboration, which is the ability to describe in detail the steps in formulating a solution; and (4) originality, which is the ability to create ideas or solutions that are unique and innovative in addressing problems.

Research conducted by Dewi et al. (2019) revealed that creative thinking skills in Indonesia are still relatively low. This finding is reinforced by the results of a preliminary study conducted on Barunawati Surabaya high school students, which showed that the achievement of creative thinking skills in each indicator was still in the low category, namely 11% for fluency, 34% for flexibility, 15% for elaboration, and 17% for originality. Creative thinking skills have an important role for students as a provision in facing various challenges in the future. Therefore, the learning process in schools needs to continue to be adapted and developed to encourage the growth of creativity, which includes creative thinking skills, attitudes, and creative behavior (Fahmi & Wuryandini, 2020). These skills can also be integrated into a variety of subjects, including chemistry subjects.

Chemistry is one of the branches of natural science that focuses its study on the composition, structure, properties, and changes of matter, ranging from the atomic to molecular levels, including various interactions that occur in the process of forming a substance (Rosmiati, 2022). One of the topics taught in chemistry is chemical bonding. This material is often considered quite complex and challenging for students to understand (Ramdhani et al., 2020). In connection with this, the application of a project model is considered appropriate to be used as an approach that can help students understand the concept of chemical bonding more easily and meaningfully.

The implementation of project activities in learning can be integrated through the PjBL model. PjBL emphasizes on solving challenging questions as well as complex tasks that encourage learners to design solutions, solve problems, manage work in a structured manner, and produce real products. One of the advantages of *the Project Based Learning* model is its ability to represent learning concepts or theories into the form of concrete products that are simple and easy to understand, where the products are independently designed by students (Rifai et al., 2021). Through the process of making projects, students' creative thinking skills can be improved, especially in the aspects of innovation and problem solving. The creativity of students is reflected in the quality of the project results they produce (Meldawati et al., 2023).

Building on the background described, this study aims to develop and assess the quality of a Project-Based Learning (PjBL) based Learner Activity Sheet (LAPD) on chemical bonding. It is anticipated that this LAPD will not only help students better comprehend the subject matter but also sharpen their creative thinking through its project-oriented activities. Ultimately, the developed product is also intended to contribute as a practical resource for educators using a project-based methodology for teaching chemical bonding.

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Research Method

This research method refers to the stages in the 4D development model proposed by Thiagarajan and Semmel (Thiagarajan et al., 1974). The research subjects included 31 students of class XI MIPA at SMAS Barunawati Surabaya. Data collection in this research was conducted using six primary instruments: validation sheets, observation sheets for both student activity and learning implementation, a student response questionnaire, a test for creative thinking skills, and a test for learning outcomes. Validity, practicality, and effectiveness are the three primary criteria that establish the feasibility of a learning tool.

The feasibility of learning devices (LAPD) from the validity aspect is reviewed based on two types of validity, namely content validity and construct validity. The validation process is conducted using a validation sheet, which is evaluated by three experts competent in their respective fields. The assessment of the product is carried out using a four-scale Likert scale, namely from a score of 1 to 4. Each score level on the scale has detailed assessment criteria that have been determined.

Table 1. Likert Scale Score

Rating Scale	Assessment Criteria
1	Very Bad
2	Bad
3	Good
4	Excellent

(Riduwan, 2015)

To analyze this data, the mode method is used, where the decision for each aspect is determined based on the score that appears most often, provided that the minimum score is 3. An aspect or indicator is determined to be valid when the validity analysis shows a modal score of 3 or greater from the validator's assessment (Yahya & Lutfi, 2023).

The assessment of the LAPD's practicality was based on three sources of data: student response questionnaires, observations of student activities, and observations of the learning implementation.Further explanation of practicality is presented below. The scores from the response questionnaire were then calculated using a Guttman scale, with reference to the scoring guidelines listed in Table 2.

Table 2. Guttman Scale

Answer	Score
Yes	1
No	0

The percentage of practicality is calculated after all scores are obtained, utilizing the following formula.

$$P(\%) = \frac{Jumlah\ skor}{Jumlah\ skor\ total} \times 100\%$$

Table 3 lists the four levels of practicality criteria used to categorize the percentage score obtained from the student response questionnaire

Table 3. Interpretation of Response Score

Score Interval	Positive Criteria	Negative Criteria
0 – 20	Very Bad	Excellent
21 – 40	Bad	Good
41 – 60	Pretty Good	Pretty Good
61 – 80	Good	Bad
81 – 100	Excellent	Very Bad

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For the assessment of the LAPD's practicality, an analysis of the student response questionnaire data was conducted. The LAPD is deemed practical if the mode of student responses falls into the 'good' or 'very good' category. The data for student activity was gathered by means of a Likert scale assessment, the specifics of which are outlined in the subsequent table 4.

Table 4. Likert Scale Score

Score	Valuation
0	Very Bad
1	Bad
2	Pretty Good
3	Good
4	Very Good

The data presented in Table 4 indicates that the project-based learning LAPD for chemical bonds achieves a 'practical' to 'very practical' rating, as its modal score is ≥ 3 ('good' to 'very good'). It is important to note that this activity data functions as a supplementary indicator, contributing to the final determination of the LAPD's overall practicality (Yahya & Lutfi, 2023). The data for learning implementation activities was obtained by means of Likert scale ratings, the specifics of which are outlined in the subsequent table.

Table 5. Likert Scale Score

Score	Valuation
0	Very not good
1	Not good
2	Pretty good
3	Good
4	Not good

(Adaptation Riduwan, 2015)

Data from the implementation of the learning process is used to support the final practicality assessment of the LAPD. As shown in Table 5, the tool is deemed 'practical' to 'very practical' if it achieves a modal score of at least 3, which corresponds to the 'good' or 'very good' category.

The LAPD's effectiveness in fostering creative thinking was measured by comparing pretest and posttest results from both creative thinking skills tests and learning outcomes tests. To ensure the data met the required assumptions, a normality test was conducted on the pretest and posttest results at a 0.05 significance level. Following this, a t-test was employed for the hypothesis testing of the creative thinking skills data to identify any significant differences. The learning outcomes data, in contrast, was analyzed by calculating the n-gain. Here is the formula for calculating the n-gain score.

$$N - gain\ (\%) = \frac{nilai\ posttest - nilai\ pretest}{nilai\ maksimum - nilai\ pretest} \times 100\%$$

The calculated n-gain score is then classified into categories, which are detailed in the subsequent table.

Table 6. Category N-gain Learning Outcomes

Value	Category
N-gain < 0,3	Low
0,3 ≤ g < 0,7	Medium
N-gain ≥ 0,7	High

(Hake, 1998)

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As detailed in Table 6, the criterion for effectiveness is an n-gain score of 0.3 or higher. A score of 0.3 signifies the beginning of the 'moderate' effectiveness category, while a score of 0.7 marks the threshold for the 'high' category.

To further analyze the creative thinking skills data, a Paired Sample t-Test was conducted using SPSS. This statistical procedure was preceded by a normality test to verify the normal distribution of both pretest and posttest data. The subsequent t-test was then performed to formally test the hypothesis regarding the effectiveness of the developed LAPD in improving students' creative thinking skills.

Results and Discussion

The primary focus of this research was the development of a product, specifically a Project-Based Learning (PjBL) oriented Learner Activity Sheet (LAPD), with the objective of fostering students' creative thinking abilities. A trial phase for the developed product was conducted at SMAS Barunawati Surabaya. What follows is a presentation of the findings from each stage of the research.

Definition Stage (Define)

The LAPD developed must be adapted to the school curriculum and relevant educational materials used in teaching and learning activities. This project-based LAPD is adapted to chemical bonding material. Chemical bonding material in the independent curriculum is taught to students in grade XI SMA, where the age ranges from 16-17 years. When associated with Piaget's theory, these students enter the formal operational stage (Wardani, 2022). One of the specific objectives of this learning media is to develop students' creative thinking skills through the project work provided (Ramadhani & Reflina, 2024).

Data gathered from observations and interviews with chemistry teachers at SMAS Barunawati Surabaya indicated a limited application of learning media in their instructional practices. Teachers tend to use the lecture method and learning media is limited to modules and school textbooks. The teacher mentioned that students find it difficult to understand chemical bonding material. One example of students' mistakes in understanding chemical bonding material is not being able to distinguish bonding compounds, especially between ion bonds and covalent bonds. Corroborating this, the assessment of the pre-research test data revealed that all indicators of creative thinking skills fell into the 'low' category, with scores of 11% for fluency, 34% for flexibility, 15% for elaboration, and 17% for originality. Therefore, teaching materials are needed that can facilitate the active involvement of students and stimulate their creative thinking skills. Based on this need, a project-based printed LAPD was developed, taking into account the characteristics of learners and the basic competencies to be achieved.

Design Stage

After the problem is identified at the definition stage, the process continues with product design (*Design*). The initial step in the planning phase is to create the LAPD. The preparation of the LAPD begins with the selection of media that is in accordance with the material and the learning objectives that have been formulated. Furthermore, the right format is chosen so that the LAPD meets the criteria of a good LAPD. This LAPD contains 4 indicators of creative thinking skills, namely *fluency*, flexibility, *originality*, and elaboration (Hidayah et al., 2021). This research resulted in 3 LAPDs. The first LAPD discusses ion bonds, the second LAPD discusses covalent bonds, while the third LAPD discusses metal bonds. Furthermore, supporting instruments for the LAPD were prepared, which included media validation sheets, student response questionnaires to the use of LAPD, observation

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sheets of student activities during the learning process, observation sheets on learning implementation, as well as pretests and posttests to measure aspects of creative thinking skills and learning outcomes (cognitive).

Development Stage

At the development stage, the main focus is to produce an LAPD that meets the eligibility criteria. The learning tools are compiled, then validated and refined based on input and suggestions from experts. After that, a follow-up trial was carried out on students in class XI MIPA SMAS Barunawati Surabaya.

Validity LAPD

The empirical justification for the developed LAPD's validity stems from the results of the validation instrument that was administered. Based on the validation results, the product has been declared to meet the user criteria. However, improvement is still needed by referring to the criticism and suggestions given by experts through the assessment sheets that have been provided. The validation data obtained was used to determine the level of validity of the LAPD developed, with reference to the aspects of content validity and construct validity (Suryani & Rusmini, 2022). The LAPD is declared valid if the aspects assessed obtain a score mode ≥ 3,which is included in the good to very good category, so that the LAPD can be interpreted as suitable for use in the learning process (Yahya & Lutfi, 2023).

The assessment of the validity of the LAPD content is based *on project-based learning* related to the structure or sususususng of the LAPD. According to the content validity assessment, the outcome meets the 'very good' criterion, as evidenced by a mode of 4. This finding suggests the LAPD was designed effectively according to several key principles. It is consistent with the Merdeka curriculum, its content is adapted to the students' proficiency levels, and it integrates creative thinking skills in a way that enhances the comprehension of chemical bonding material. Furthermore, assessment in the language aspect is related to how language is used to explain chemical materials in the LAPD. The validity assessment was rated 'very good', with a resulting modal score of 4. This shows that the LAPD has been developed to use clear and easy-to-understand language and terms, so that it can support students' understanding of chemical bonding materials more effectively.

The assessment of the LAPD's presentation aspect is related to the quality of visual appearance and the integration of elements presented in the LAPD. According to the validity assessment, the outcome meets the 'very good' criterion, as evidenced by a mode of 4. This suggests that the developed LAPD can enhance students' motivation to learn and interest in reading, in addition to fostering their active engagement in learning activities. The evaluation of the graphic design elements, specifically the use of illustrations and images within the LAPD, yielded a 'very good' validity rating based on a modal score of 4. This result suggests that the visual components are organized in a clear and informative way, thereby enhancing readability and student comprehension.

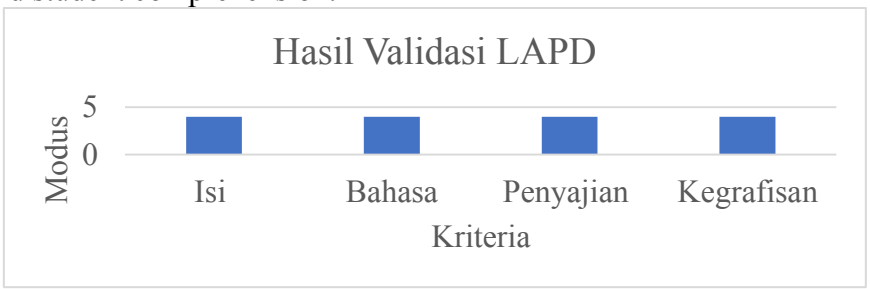

Figure 1. LAPD Validation Results

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As shown in Figure 1, both the content and construct validity assessments yielded an overall modal score of 4, corresponding to a 'very good' rating. Therefore, the LAPD is declared valid for use in practicing students' creative thinking skills. The validation methodology employed in this study is comparable to that of Hanifah & Hidayah (2024), who reported achieving a modal score of 4 ('very good' category) for both content and construct validity. Furthermore, the overall finding of high validity in our study corroborates the research of Yerimadesi and Afendi (2024), which affirmed the validity of their learning media across linguistic, presentational, and graphical aspects.

LAPD Practicality

The practicality of the LAPD was assessed by analyzing student responses after its use. A 23-statement questionnaire was employed as the instrument, evaluating aspects such as the suitability of the project-based learning model, indicators of creative thinking skills, the ease of understanding the chemical bonding material, and the overall usability of the LAPD. An analysis of these student responses is presented in Figure 2.

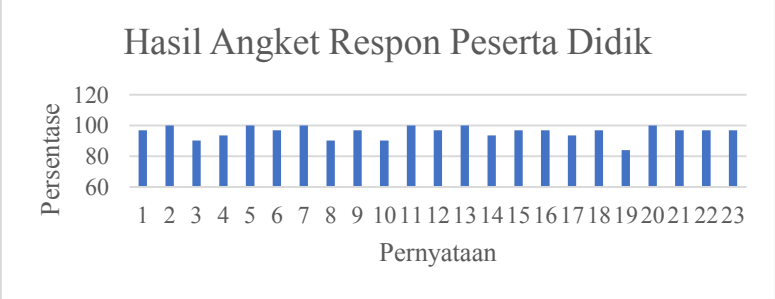

Figure 2. Results of the Student Response Questionnaire

As shown in Figure 2, the overall student response questionnaire yielded 'good' to 'very good' scores, which proves that the developed Project-Based Learning LAPD meets the practicality criteria. Further evidence for the LAPD's practicality comes from observations of student activities and learning implementation. Three supervisors evaluated creative thinking skills and PjBL stage fidelity over three meetings covering ion, covalent, and metal bonds. The results of these observations are shown in Figures 3 and 4.

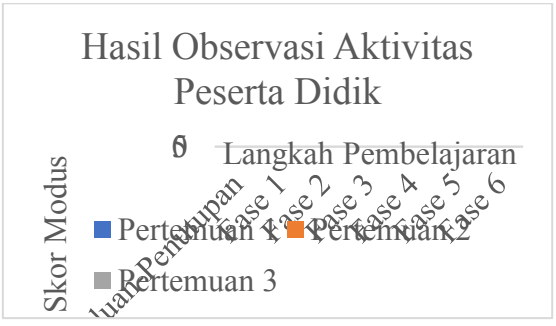

Figure 3. Results of Observation of Student Activities

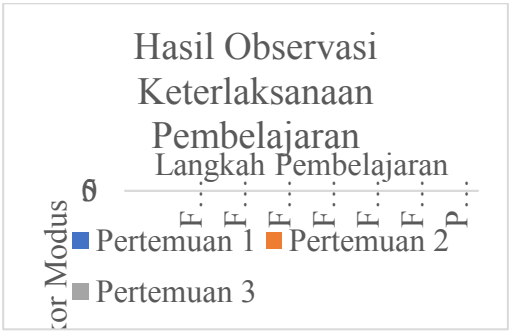

Figure 4. Learning Implementation Results

The data reveals a high level of performance in both key areas of observation. Figure 3 indicates that overall student activity achieved a modal score of 4 ('very good'), and likewise, Figure 4 illustrates that the overall learning implementation received the same 'very good' rating. These results suggest that the LAPD facilitated an effective learning environment that adhered to the intended PjBL framework and successfully integrated the indicators of creative thinking skills. The collective evidence from student response questionnaires, activity observations, and learning implementation observations confirms the

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high practicality of the developed Project-Based Learning LAPD. This result is consistent with previous research findings that rated learning media for Phase F high school students as 'very practical' with respect to its ease of use, efficiency in learning time, and the advantages gained from its application. (Yerimadesi & Afendi, 2024).

The effectiveness of the LAPD

To measure the effectiveness of the LAPD developed, research instruments were used in the form of learning outcome tests that included knowledge and creative thinking skills, through the implementation of pretests and posttests before and after limited trials of LAPD products. The knowledge assessment was conducted using a 10-item multiple-choice instrument focused on chemical bonding materials. A comparison of pretest and posttest data yielded an average N-Gain value of 0.85, indicating a high level of improvement. This is further supported by the increase in average scores from 20 (pretest) to 87.74 (posttest). For a more granular analysis, Figure 5 provides the pretest and posttest results for each individual test item.

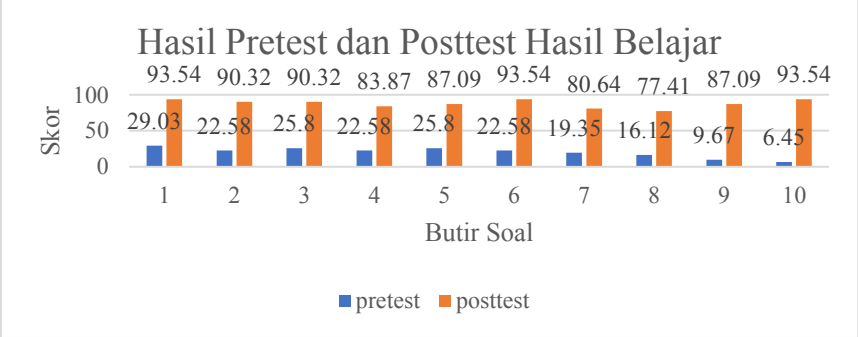

Figure 5. Pretest and Posttest Results of Each Question Item

Table 7 displays the pretest, posttest, and N-gain scores for students' creative thinking skills. This data was gathered using an eight-question test instrument that covered the four main indicators of fluency, flexibility, originality, and elaboration.

Table 7. N-gain Score for Each Indicator of Creative Thinking Skills

Indicators of Creative Thinking Skills	*Pretest*	*Posttest*	N-Gain	Category
Fluency	28,38	90,32	0,86	High
Flexibility	29,03	90,32	0,86	High
Originality	27,41	89,67	0,85	High
Elaboration	27,74	90,64	0,87	High

The data presented in Table 7 demonstrates a significant improvement in each assessed aspect of creative thinking. Specifically, the N-gain values for fluency (0.86), flexibility (0.86), originality (0.85), and elaboration (0.87) all correspond to a 'high' level of effectiveness. Therefore, it is concluded that the LAPD is an effective instrument for fostering students' creative thinking abilities. This result corroborates the findings of Mirfaka et al. (2023), which concluded that the implementation of project-based learning models provides an effective approach to enhancing creative thinking abilities.

To complement the N-Gain analysis, the creative thinking skills data was subjected to a Paired Sample t-Test using SPSS. This procedure was contingent upon a preliminary Shapiro-Wilk test to confirm data normality, the results of which are detailed in Table 8.

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Table 8. Pretest and Posttest Normality Test Results for Creative Thinking Skills

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Before	.174	31	.018	.949	31	.147
After	.144	31	.102	.936	31	.064

A test for normality was conducted using the Shapiro-Wilk method, with results presented in Table 10. The pretest (p = 0.147) and posttest (p = 0.64) data both returned significance values above the 0.05 threshold, indicating a normal distribution. Consequently, the data met the necessary assumptions for a paired sample t-test, the outcomes of which are detailed in Table 9.

Table 9. Results of Paired Sample t-Test Creative Thinking Skills

		Paired differences			95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std, Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Pre-Pos	-62.09677	4.96222	.089124	-63.91693	-60.27662	-89.674	30	.000

The results of the paired sample t-test, detailed in Table 9, were significant (p < 0.05). The obtained t-statistic was 69.674, surpassing the critical t-value of 2.042. This outcome provides sufficient evidence to reject the null hypothesis (H_0) in favor of the alternative hypothesis (H_a). This indicates a statistically significant improvement in students' creative thinking skills on the topic of chemical bonding following the implementation of the LAPD, thereby demonstrating the tool's effectiveness. The outcomes of this research corroborate the conclusions of Sari et al. (2019) which posit that the PjBL model is an effective method for fostering creative thinking skills. The rationale provided is that PjBL's student-centered nature, combined with direct experience from project creation, cultivates a broader mindset. This, in turn, facilitates the generation of diverse inquiries and solutions and promotes original thought, allowing students to develop novel ideas.

Conclusion

In light of the preceding findings and discussion, the conclusion of this study is that the Project-Based Learning LAPD is a feasible medium for developing students' creative thinking skills on the topic of chemical bonding. The feasibility is substantiated by three criteria. The tool's validity was affirmed with 'very good' ratings (mode = 4) for both content and construct validity. Its practicality was demonstrated through a high student response percentage (95.79%) and 'very good' modal scores (mode = 4) for both observed student activities and learning implementation. The learning tool is shown to be both very practical, based on the three aspects previously discussed, and highly effective. The effectiveness is supported by multiple lines of evidence: high N-gain scores (0.85-0.87) in all creative thinking indicators, a significant Paired Sample t-Test result (p < 0.05), and a high N-gain score (0.85) for cognitive learning outcomes.

Recommendation

In light of the research findings, the researcher would like to offer several suggestions for future work:

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1) Further research that implements *the Project Based Learning* (PjBL) model is recommended to design project time allocation in a more structured manner, in order to optimize the achievement of student learning outcomes.
2) Students should be involved more often in project activities, so that their creative thinking skills can continue to develop in chemistry learning, not only limited to chemical bonding materials, but also to other materials.

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