The implementation of PJBL-STEAM model on eleven graders' creative thinking skills through *jumputan* batik pattern-making project of acid-base-related material

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Abstract
This mixed-method research aimed to analyze the influence of the PjBL-STEAM learning model on the creative thinking skills of grade XI students through a *jumputan* batik pattern-making project. The main problem was the demand for creative adaptation skills in the 21st century. By collecting data through product assessment observations, questionnaires, and interviews, this study found that the PjBL-STEAM model had a positive and strong impact, particularly in the aspects of fluency and flexibility, which reached 75.50%–78.00%. However, significant challenges were found in the aspects of originality and elaboration, with lower scores (52.27%–58.20%), indicating the need for further development on the innovation and detail of students' work. Overall, the PjBL-STEAM model is effective, but it requires more specific guidance to encourage the generation of unique and detailed ideas.

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1. Introduction

The era of the industrial revolution 4.0 in the 21st century is accompanied by the rapid development of science, technology, information, and education. There are 4 essential skills required in the 21st century: critical thinking skills, collaboration skills, communication skills, and creativity skills (Zayyinah et al., 2022). Among these, one of the important skills in various fields, such as the field of education, is creative thinking. According to (Munandar, 2009), creativity is the ability to produce new combinations of existing data, information, or elements. Creative thinking skills refer to a higher-level thinking process that combines logical and divergent reasoning to develop new ideas, solutions, and inventions (Oanh & Dang, 2025). Creativity is crucial in learning because it helps students develop their imagination and build critical thinking skills (Kurniawan et al., 2024).

Creative thinking is essential as it contributes to problem-solving ability in various ways (Siburian et al., 2019; Zubaidah et al., 2017). To enhance creative thinking skills, appropriate strategies, synergy with critical thinking, and integration as part of higher-order thinking skills are required (Huang et al., 2020). Moreover, creativity plays a crucial role in optimizing understanding and supporting students' cognitive development (Sari et al., 2018). Individuals with strong creative thinking skills tend to be more confident and are generally more likely to achieve higher academic performance (Apriwanda & Hanri, 2022; Ernawati et al., 2019; Vong & Kaewurai, 2017).

The low level of creative thinking in Indonesia has been reflected in various survey results. The results of the Programme for International Student Assessment (PISA) 2022 survey reported that only 5% of Indonesian students were classified as proficient in creativity, while 31% of Indonesian students demonstrated only basic creativity skills, much lower than the average for all OECD countries (78%) (OECD, 2022). Similarly, Indonesia ranks 115 out of 139 countries in the world based on Global Creativity Index (GCI) research in 2015 (Mariani & Indriyanti, 2024). This implies that students' cognitive abilities need to be continuously improved. Creative thinking skills can be cultivated or improved through classroom learning by applying models designed to train creative thinking skills (Purwati & Alberida, 2022). One of them is the PjBL-STEAM learning model.

Project-Based Learning (PjBL)- Science, Technology, Engineering, Art, and Mathematics (STEAM) is an ideal learning model to achieve 21st-century education goals because it involves 4C skills. PjBL is a student-

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centered learning model that encourages independence through problem-solving. A distinctive feature of this model is that students can apply various skills to complete real and useful tasks (Rohman et al., 2024). STEAM is a learning approach that combines various disciplines to develop creative and collaborative thinking skills (Wu, 2022). This approach focuses on group problem solving that encourages students to work together, appreciate each other's roles, and learn from their different interests, abilities, and backgrounds (Suryani et al., 2024). The PjBL model has proven effective in fostering meaningful student engagement in science learning by providing direct experiential opportunities, with teachers acting as facilitators to promote student-centered conceptual understanding (Afriana et al., 2016; Hsu & Liao, 2018; Misbah et al., 2024). The PjBL model is effective in developing creative thinking, critical thinking, and also problem-solving (Rohman et al., 2024).

The application of the PjBL-STEAM model has previously been successfully carried out by Annisa et al. (2019) implementing the project design in the form of developing natural indicators and designing electrical circuits to test the conductivity of the acid-base solution and calculate the pH of each solution. Likewise, Apriliana et al. (2017) also succeeded in implementing PjBL-STEAM of acid-base materials with a project in the form of making natural indicators using purple cabbage in an acid-base solution by observing the color changes that occurred. Their findings concluded that project-based learning in acid-base materials can enhance students' soft skills, such as creative thinking, critical thinking, and collaboration.

Chemistry is an important subject for students as it can foster creative thinking, yet many students often have difficulties learning chemistry concepts (Zephrinus et al., 2015). One of the main reasons students find many chemistry concepts difficult is the high level of abstraction of these concepts, and the teachers often do not have the necessary resources to make them more concrete through laboratory demonstration and experimentation (Zephrinus et al., 2015). Acid–base chemistry is recognized as a difficult concept at the high school level (Demircioğlu et al., 2005). Acid-base concepts require experimental activities that lead to meaningful chemistry learning so that students do not merely receive the material, but also engage as active individuals (Artdej et al., 2010).

An example of such an experiment that supports understanding the concept of acid-base is the creation of a *jumputan* batik pattern. Making a unique and interesting batik pattern using natural dyes, such as turmeric, indigo, beetroot, noni fruit, and carrots can be an example of an experiment to understand the concept of acid-base-related material. In this case, *jumputan* batik can be a good choice because it has a variety of interesting patterns and natural dyeing techniques. *Jumputan* batik is made by tying or gathering cloth using rope, and then dipping it in dye to create the desired pattern (Atmojo, 2015). Besides, batik can be used as a medium to develop students' creative thinking because they can create works based on their respective creativity (Sudarmin et al., 2020).

Based on the background described, numerous studies have implemented the PjBL-STEAM model in acid-base materials by making natural indicators to test acid-base solutions. However, this study introduces innovation by utilizing natural acid-base indicators in the process of creating *jumputan* batik patterns. The *jumputan* batik-making project directly integrates the STEAM concept encouraging students to think, collaborate, and produce work creatively. In addition, the PjBL-STEAM model is also in line with the objectives of P5 in forming the character of independent, creative, and innovative students.

2. Method

This study was using mixed-method design. This research was conducted in one of the public high school in Surakarta region. The population of the study was all students of grade XI who took chemistry subjects consisting of three classes, namely (XI F1, XF2, and XI F3) with a total of 108 students. The sample was selected through the Cluster Random Sampling technique by testing homogeneity and normality using the mid-term summative assessment (PSTS) scores. The Shapiro-Wilk test was used to test normality while the Levene's test was used to test homogeneity. The selected sample was class XI of Phase F3. The results of the normality and homogeneity tests can be seen in Table 1 and Table 2.

Table 1. The Results of the Sampling Normality Test

Sources	Classes	Sig.	α = 5%	Results
The results of PSTS	XI F1	0.250	0.05	Normal
	XI F2	0.116	0.05	Normal
	XI F3	0.207	0.05	Normal

Table 2. The Results of the Sampling Homogeneity Test

Sources	Sig.	α = 5%	Results
The results of PSTS	0.475	0.05	Homogenous

In this study, the instruments used were non-test technique. Non-test instruments consisted of product assessment sheets, questionnaires, and interviews. A total of 6 statements in the product assessment sheet were used to measure creative thinking skills on the quality and success of projects produced by students in PjBL activity. The questionnaire used was a closed questionnaire in the form of a checklist using a Likert scale consisting of 1-5 with 10 statements. The data collected were ordinal. The instruments were validated by one supervisor and one teacher. Afterwards, a content validity test was carried out using the Gregory formula. The product assessment sheet and the questionnaire received a score of 0.8, which indicated a very high level of validity. The instruments were then tested and checked for reliability using the Cronbach's Alpha formula with the help of SPSS 22. The product assessment sheet obtained a value of 0.707, while the questionnaire obtained a value of 0.887, showing that both instruments were highly reliable within the range of 0.70-0.90 (Artdej et al., 2010).

The data collected were ordinal. Afterwards, the data were converted into interval data using the Method of Successive Intervals (MSI) test with the help of Microsoft Excel. Furthermore, the conversion results were analyzed parametrically using the SPSS 22 statistical tool. The MSI test was intended to make the data normally distributed so that parametric statistical requirements can be fulfilled.

The collected data were then grouped based on the research objectives. Then, they were presented in the form of tables and graphs with conclusions drawn from the results of the data processing. The qualitative data analysis process included three main stages: data reduction, data presentation, and conclusion drawing.

3. Results and Discussion

At the first meeting, students were given a reflection by observing a video about an experiment on making natural indicators of acid-base and *jumputan* batik. Afterward, students were divided into seven groups to discuss and solve problems related to the acid-base concept. Each group then designed a project plan for the second meeting. In the second meeting, students worked collaboratively with their group on the project according to the design they had prepared. The materials and tools used included colored plant extracts, soap, vinegar, mori cloth, rubber, rulers, pencils, glasses, and spoons. Next, students observed the color changes that occurred when plant extracts were added to acid-base solutions. The resulting color were then used as a dye to create *jumputan* batik. The batik cloths were subsequently dried in the sun for 7 days. At the final meeting, students reflected on the project-making process and teachers interviewed 7 students.

3.1. Results of Product Assessment Sheet Distribution

The decision-making was carried out with the criteria shown in Table 3.

Table 3. MSI Primary Calculation Product-Based Assessment Sheet Decision Criteria

Criteria	Frequency
Very good	10
Good	12
Sufficient	12
Poor	2

Table 3 shows that, in terms of creative thinking to produce a product, the majority of the students (34 out of 36) belong to the sufficient, good, and very good categories. However, 2 students still belonged to the poor category. The reason these two students received low scores was because during the learning process, they were passive, indifferent, and lacked creative thinking. According to Purwati & Alberida (2022), learning conditions that tend to be passive make students unable to generate creative ideas in solving problems from various points of view.

3.2. Distribution of Questionnaire Assessment Results

The decision-making was carried out with the criteria shown in Table 4.

Table 4. MSI Primary Calculation-Based Questionnaire Decision Criteria

Criteria	Frequency
Very good	6
Good	5
Sufficient	16
Insufficient	7
Poor	2

Table 4 shows that the majority of students belonged to the fairly good category. However, there was 2 students who belonged to the very poor category. Several factors such as lack of interest in learning, lack of understanding of acid-base-related material, passively contributing to project work, or even discomfort in filling out the questionnaire, caused this to occur (Hao et al., 2016).

3.3. The Results of Creative Thinking Skill Indikator Sheet-based Product Assessment

The percentage achievement (%) of the Product Assessment Sheet measuring the creative thinking skills of the XI F3 class consisting of 36 students can be seen in Table 5.

Table 5. Percentage Achievement (%) of Product Assessment Sheet

Aspects	Indicators	Criteria	Achievement Percentage (%)	Students
Fluency	Expressing various ideas/concepts, answers, or problem-solving.	Skills related to combining natural acid-base materials to produce unique new colors.	75.50	27
Flexibility	Providing a variety of ideas, questions, and answers	Skills related to creating variations of natural colors produced from different acid-base materials	78.00	28
	Thinking of different alternatives or directions	Skills related to making many variations of batik patterns	50.50	18
Originality	Creating various unique combinations of various parts and various elements	The utilization of unique and innovative tie-dye tools and techniques	52.27	19
	Searching for unique ways to show someone's creativity	The use of mathematical formulas in calculating the ratio of materials and making batik patterns	58.20	21
Elaboration	Providing more details of an object, idea, or situation to make it more interesting	The conformity of the pattern design to the final pattern based on the manufacturing process	58.20	21
Averages			62.21	

After that, the Product Assessment Sheet was analyzed based on the percentage of creative thinking achievements measured through several aspects based on Torrance and Guildford's theory including fluency, flexibility, originality, and elaboration. Each aspect has an indicator.

Fluency is a skill related to producing various ideas and solutions (Pratiwi et al., 2019). In the fluency indicator, expressing various ideas or concepts, answers, and problem-solving, showed a percentage achievement of 75.50%. This percentage indicated that 27 students have good skills in producing various ideas by combining natural acid-base ingredients to produce several interesting new colors. Students combining several ingredients are depicted in Figure 1.

Figure 1. Students are combining several materials to produce new colors

Flexibility is a skill related to producing various strategies (Pratiwi et al., 2019). In the first flexibility indicator, providing various variations of ideas, questions, and answers, the results reached 78.00%. This shows that 28 students were very flexible in creating various color results from different materials. The colors obtained were orange, yellow, pink, green, brick red, and purple. Some of the colors produced by students can be seen in Figure 2.

Figure 2. Students are producing color variations from natural acid-base materials

The second flexibility indicator, providing various variations of ideas, questions, and answers, reached a much lower point, 50.50%. This significant difference indicated that 18 students might be less flexible or have less capability to think of various alternatives in the context of making batik patterns compared to the experiment of making unique color variations. The variations in batik patterns made by students can be seen in Figure 3.

Figure 3. Students are Making Batik Patterns

Originality is a skill related to producing new and unique ideas (Pratiwi et al., 2019). In the first originality indicator, creating various unique combinations of various parts or elements, the result reached 52.27% while in the second indicator, finding various unique ways to show oneself, the result was slightly higher, namely 58.20%. Although there was a slight difference in percentage, these two originality indicators were still below the overall average. This indicated that students still faced challenges in producing ideas or approaches that are truly new, unique, or innovative, especially in the context of *jumputan* art and the application of mathematics in batik. Practically, students generally used tools such as rubber, pencils, markers, and rulers. Most of them applied the *jumputan* technique by directly tying the fabric using rubber without the help of small objects, such as pebbles or marbles. The application of the originality aspect is portrayed in Figure 4.

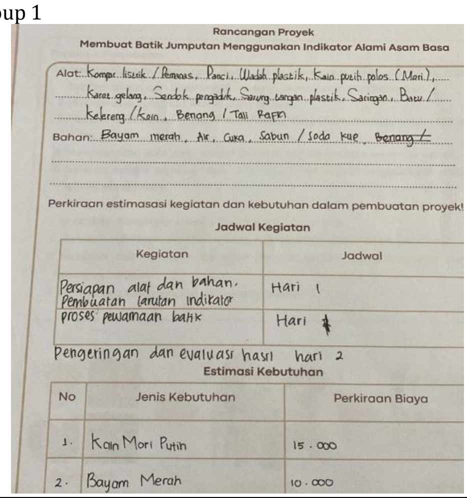
Figure 4. Application of the Originality Aspect

Elaboration, a skill of developing ideas in detail (Pratiwi et al., 2019), became the last aspect. In the elaboration indicator, providing details of an object, idea, or situation in more detail to make it more interesting, showed a percentage achievement of 58.20%. This result showed that the ability of 9 students to provide details of an idea to make it more interesting still needed improving. The inaccuracy in the design process to the final implementation could be the determining factor. The initial design and final results can be seen in Table 6.

Table 6. The Initial Design and Final Results of the *Jumputan* Batik Project

Initial designs	Final results

Group 1



Rancangan Proyek
Membuat Batik Jumputan Menggunakan Indikator Alami Asam Basa

Alat: Kompor listrik / Pemanas, Panci, Wadah plastik, Kain putih polos (Mori), Karet gelang, Sendok pengaduk, Sarung tangan plastik, Saringan, Batu / Kelereng / Kain, Benang / Tali Rafia

Bahan: Bayam merah, Air, Cuka, Sabun / Soda kue, ~~Benang /~~

Perkiraan estimasasi kegiatan dan kebutuhan dalam pembuatan proyek!

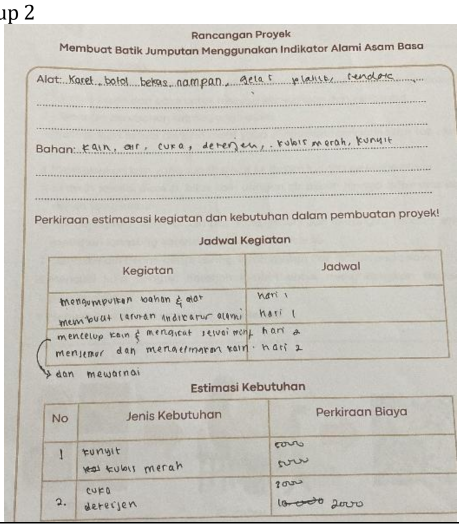
Jadwal Kegiatan

Kegiatan	Jadwal
Persiapan alat dan bahan. Pembuatan larutan indikator	Hari 1
proses pewarnaan batik	Hari 1
Pengeringan dan evaluasi hasil	hari 2

Estimasi Kebutuhan

No	Jenis Kebutuhan	Perkiraan Biaya
1.	Kain Mori Putih	15.000
2.	Bayam Merah	10.000

Group 2



Rancangan Proyek
Membuat Batik Jumputan Menggunakan Indikator Alami Asam Basa

Alat: Karet, botol bekas, nampan, gelas plastik, sendok

Bahan: kain, air, cuka, deterjen, kubis merah, kunyit

Perkiraan estimasasi kegiatan dan kebutuhan dalam pembuatan proyek!

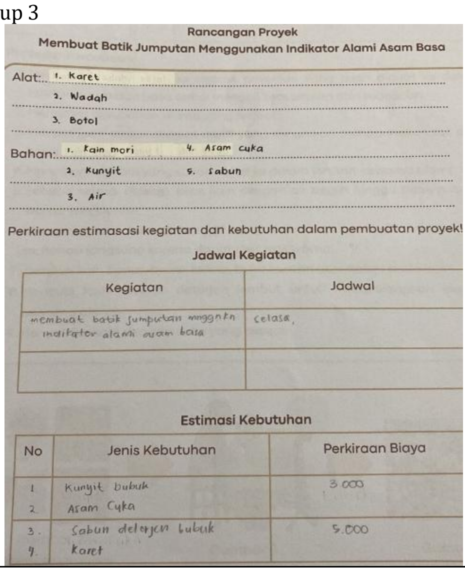
Jadwal Kegiatan

Kegiatan	Jadwal
mengumpulkan bahan & alat membuat larutan indikator alami	hari 1 hari 1
mencelup kain & mengikat sesuai motif dan mewarnai menjemur dan mengeringkan kain.	hari 2 hari 2

Estimasi Kebutuhan

No	Jenis Kebutuhan	Perkiraan Biaya
1	kunyit kubis merah	5000 5000
2.	cuka deterjen	2000 ~~1000~~ 2000

Group 3



Rancangan Proyek
Membuat Batik Jumputan Menggunakan Indikator Alami Asam Basa

Alat: 1. Karet
2. Wadah
3. Botol

Bahan: 1. Kain mori 4. Asam cuka
2. Kunyit 5. Sabun
3. Air

Perkiraan estimasasi kegiatan dan kebutuhan dalam pembuatan proyek!

Jadwal Kegiatan

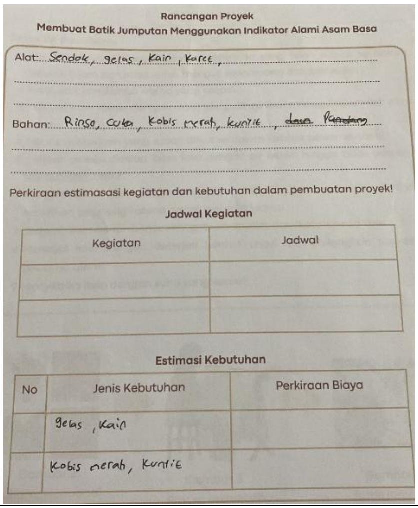
Kegiatan	Jadwal
membuat batik jumputan mnggnkn indikator alami asam basa	selasa,

Estimasi Kebutuhan

No	Jenis Kebutuhan	Perkiraan Biaya
1 2	Kunyit bubuk Asam Cuka	3.000
3. 4.	Sabun deterjen bubuk Karet	5.000

Initial designs	Final results

Group 4



Rancangan Proyek
Membuat Batik Jumputan Menggunakan Indikator Alami Asam Basa

Alat: Sendok, gelas, Kain, Karet,

Bahan: Rinso, Cuka, Kobis merah, kunyit, ~~daun Pandan~~

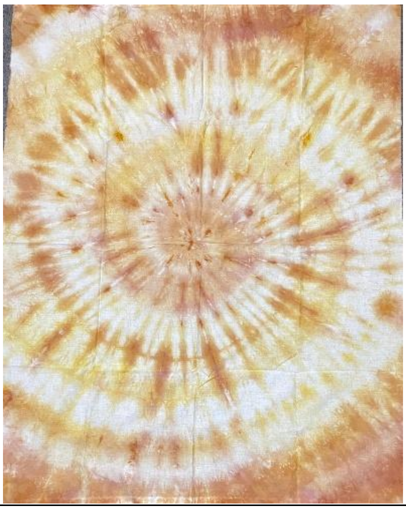
Perkiraan estimasasi kegiatan dan kebutuhan dalam pembuatan proyek!

Jadwal Kegiatan

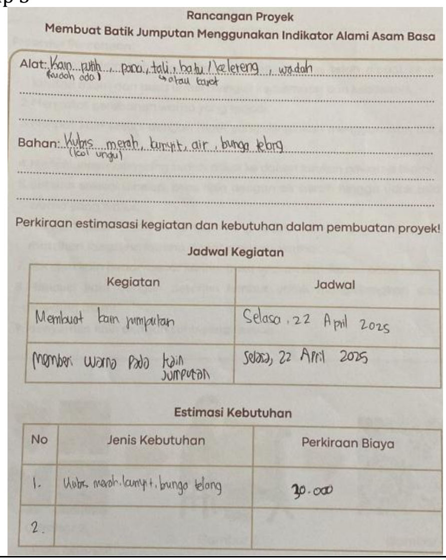
Kegiatan	Jadwal

Estimasi Kebutuhan

No	Jenis Kebutuhan	Perkiraan Biaya
	gelas, Kain	
	Kobis merah, Kunyit	



Group 5



Rancangan Proyek
Membuat Batik Jumputan Menggunakan Indikator Alami Asam Basa

Alat: Kain putih (kalau ada), panci, tali, batu / kelereng (atau karet), wadah

Bahan: Kubis merah (kol ungu), kunyit, air, bunga telang

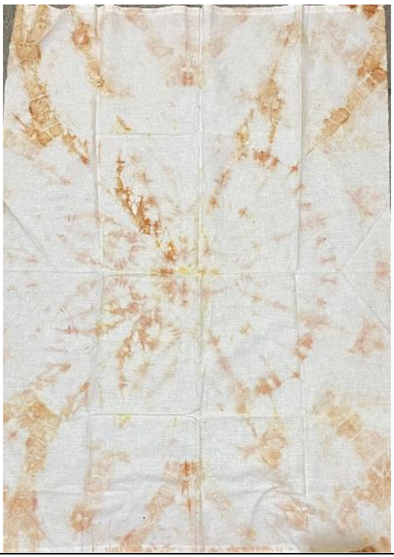
Perkiraan estimasasi kegiatan dan kebutuhan dalam pembuatan proyek!

Jadwal Kegiatan

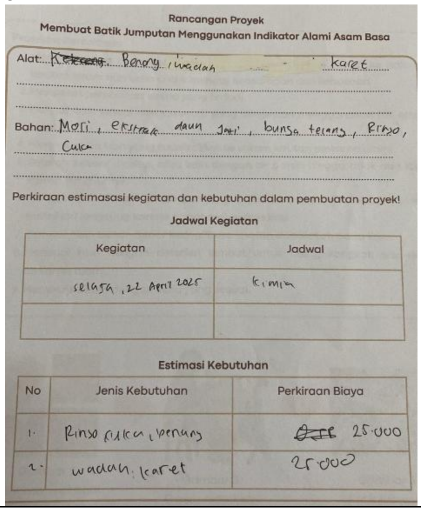
Kegiatan	Jadwal
Membuat kain jumputan	Selasa, 22 April 2025
memberi warna pada kain jumputan	Selasa, 22 April 2025

Estimasi Kebutuhan

No	Jenis Kebutuhan	Perkiraan Biaya
1.	Kubis merah, kunyit, bunga telang	30.000
2.		



Group 6



Rancangan Proyek
Membuat Batik Jumputan Menggunakan Indikator Alami Asam Basa

Alat: ~~Kelereng~~ Benang, wadah, karet

Bahan: Mori, ekstrak daun jati, bunga telang, Rinso, Cuka

Perkiraan estimasasi kegiatan dan kebutuhan dalam pembuatan proyek!

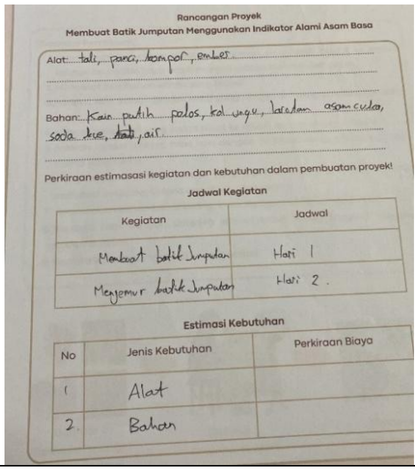
Jadwal Kegiatan

Kegiatan	Jadwal
selasa, 22 April 2025	kimia

Estimasi Kebutuhan

No	Jenis Kebutuhan	Perkiraan Biaya
1.	Rinso, cuka, benang	25.000
2.	wadah, karet	25.000

Initial designs	Final results
Group 7	



Rancangan Proyek
Membuat Batik Jumputan Menggunakan Indikator Alami Asam Basa

Alat: tali, panci, kompor, ember.

Bahan: Kain putih polos, kol ungu, larutan asam cuka, soda kue, ~~[illegible]~~, air.

Perkiraan estimasasi kegiatan dan kebutuhan dalam pembuatan proyek!

Jadwal Kegiatan

Kegiatan	Jadwal
Membuat batik Jumputan	Hari 1
Menjemur batik Jumputan	Hari 2.

Estimasi Kebutuhan

No	Jenis Kebutuhan	Perkiraan Biaya
1	Alat	
2	Bahan	

In all 7 groups, the *jumputan* batik produced by Group 3 best matched the initial design in terms of tools, materials, patterns, and colors used. The pattern created by Group 3 was a floral pattern with a combination of yellow, red, and pink colors. Meanwhile, the *jumputan* batik produced by Group 2 did not align with the initial design. The discrepancy may have occurred because of changes in patterns during the work process, the colors made were not concentrated enough, and the lack of collaboration among students.

These findings were supported by the students' interviews. The questions asked focused on the results of their batik projects and were related to the aspect of creative thinking indicators. One student said that "*The project was fun, but I had a hard time finding a pattern to use."* Such difficulties emerged because the learning process in the classroom had not yet fully developed or trained students' creative thinking skills (Purwati & Alberida, 2022) As a result, students struggled to produce unique new ideas (*originality*) and to develop ideas in detail (*elaboration*).

Overall, this learning model was perceived as new and fun for students because through the project, they can understand how chemical concepts, especially acids and bases, could be applied directly in real-life contexts, such as in the process of making batik. "*I learned that materials with acidic and alkaline properties can affect the color of the fabrics. For example, when dipping a fabric into a certain solution, the color may change depending on the pH. This made the batik process feel like an exciting experiment, because I could try different substances and directly see the color results on the fabric. It's not just about art, it's also about science – and that's what made this experience so interesting and fun*!" Based on this statement, it can be concluded that the PjBL-STEAM model was successfully implemented.

4. Conclusion

In summary, the results of the product assessment and questionnaire distribution show strong positive indications. The majority of students succeed in producing high-quality products, and respondents' perceptions of the questionnaire subjects tend to be satisfactory. However, a small number of students and respondents still need further attention or guidance to improve product quality and address aspects that are considered negative. In addition, 27 students show prominent strengths in generating ideas and solutions with a fluency aspect of 75.50% and varying the results from different materials, such as natural color combinations, with a flexibility aspect of 78.00%. This indicates that they have a good ability to generate many ideas and adapt to various inputs. In contrast, students still face significant challenges in the aspects of originality (52.27% and 58.20%) to create truly new and unique ideas, and elaboration (58.20%) in detailing ideas in depth. In addition, flexibility (50.50%) also requires substantial improvement, especially in different contexts such as making batik motifs. This indicates that students have not been accustomed to thinking innovatively or developing their ideas in sufficient detail.

Author Contributions

AKF: conceptualizing research, collecting data, processing data, and drafting manuscript; LM: conceptualizing research, validating instrument, critically reviewing and revising manuscript; EN: validating instrument, supervising during collecting data.

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The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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