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Strategies for developing creative thinking in the digital era through procreamath projects: Synergy of e-worksheets and project-based learning

Anggie Yudistira Aditya*
Universitas Madani,
INDONESIA

Lukmanul Hakim
Universitas Madani,
INDONESIA

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Abstract

Background: Creative thinking is a crucial skill in mathematics education, particularly in understanding geometric concepts such as flat side space nets. However, conventional learning resources often lack the capacity to stimulate such thinking effectively.
Aims: This study aims to develop an e-worksheet based on Project-Based Learning (PjBL) to enhance students' creative thinking skills in a geometry course, focusing on flat side space nets.
Methods: The development process follows the ADDIE model, consisting of analysis, design, development, implementation, and evaluation phases. The e-worksheet was created using digital design tools to ensure interactive and visually engaging content. Validation was conducted by subject matter and media experts, while practicality was assessed through student feedback. Effectiveness was evaluated based on the improvement of students' creative thinking skills.
Result: The validation results indicate that the e-worksheet meets the criteria for content, visual design, and alignment with the PjBL approach. Students responded positively to the e-worksheet's usability, clarity, and role in supporting conceptual exploration. Learning outcomes showed an increase in creative thinking, particularly in fluency and originality. However, lower achievement in flexibility and elaboration suggests the need for further instructional focus on these indicators.
Conclusion: The PjBL-based e-worksheet is valid, practical, and effective in enhancing creative thinking skills and is feasible for use as an alternative mathematics learning resource. Future development should emphasize activities that strengthen flexibility and elaboration aspects of creative thinking.

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INTRODUCTION

The 21st century requires individuals to have competencies that are able to improve the quality of life, including mastery of knowledge, technology, and the ability to study developments in the natural and social fields (Bayley, 2022). Education is geared towards producing graduates who are creative, innovative, intelligent, and able to compete globally Thanks et al., (2025), through a Student-cantered, collaboration-based, and goal-oriented learning paradigm (Black, 2020). So that 21st-century graduates require to have good competence. Basically, 21st century education has four main principles among being student-cantered, collaborative, connected to real life and must have a purpose.

Modern educational practices emphasize inquiry-based activities, design, and collaborative projects that place students at the centre of learning (Yudistira, 2023; Darmuki et al., 2023). This activity contributes significantly to developing original thinking skills, which is one of the main competencies of the 21st century in addition to critical thinking, communication, and collaboration

* **Corresponding author:**
Anggie Yudistira Aditya, Universitas Madani, INDONESIA
anggie@umad.ac.id

(Taar & Palojoki, 2022). The capacity for innovative thought is characterized as the talent for discovering realities, challenges, concepts, and resolution to those challenges.

Creative thinking is generally defined as the ability to find truth, formulate problems, generate ideas, and find innovative solutions (Aditya, A. Y., 2023; Kocak et al., 2021). These abilities include cognitive processes that allow individuals to respond creatively to various challenges (Chrysikou, 2020). Indicators of creative thinking include fluency, flexibility, originality, and elaboration (Voogt & Pareja Roblin, 2023). Ability can improve students' ability to come up with a variety of solutions that are not limited to conventional rational analysis, but also involve intuition and insight (Alabbasi et al., 2022). It involves using basic principles in the thought process to develop original ideas that are aesthetically and constructively valuable in the context of certain views and concepts. The creative thinking process includes the stages of observing problems, formulating assumptions, testing hypotheses, exploring alternative solutions, and communicating results (Aditya et al., 2025; Kaur et al., 2021). This ability equips students to face challenges in the world of education and real life with an original approach (Cassotti et al., 2016; Kaur et al., 2021) . Creative thinking is a force that allows every individual to face educational challenges with new methods and original solutions. So that with the learning model having students' creative skills, students can function to provide various kinds of solutions to the problems they are facing.

Project-Based Learning (PjBL) has developed as an effective pedagogical model in developing creative thinking skills. PjBL emphasizes student independence and collaboration through authentic projects, thereby increasing long-term engagement and learning outcomes (Hopper, 2014; Stehling & Munzert, 2018; Van Hooijdonk et al., 2022). A number of empirical studies show that PjBL makes a positive contribution to increasing student creativity (Sucilestari et al., 2023; Yu, 2024). PjBL encourages students to be actively involved in the learning process and look for innovative solutions in solving the problems they are facing. The PjBL process involves feedback from lecturers and peers, which helps students to reflect on ideas and develop students' creative thinking skills.

However, the effectiveness of executing PjBL relies significantly on the availability of appropriate learning tools to facilitate student activities (Lee et al., 2024; Zen et al., 2022). One of the tools that can be used is the e-worksheet, which not only contains structured exercises, but also provides a conceptual framework to support a deeper understanding (Mrazek et al., 2024; M. Shah, 2021). Research shows that PjBL-based e-worksheets are able to effectively improve students' creative abilities (Aditya, 2024; Koo & Lee, 2021; Sari, 2019; Wardani, 2021; Wilkie, 2024). As a support for learning activities that can run smoothly and be carried out properly, teaching materials are needed. On the use of many media usable during class activities such as books, PPT, e-worksheet, *e-Learning*. One of the learning media that can be used in the learning process is e-worksheet (Bare & Sari, 2021; Ishartono et al., 2024; Tai, 2024). E-worksheet is one of the learning media that can help students and lecturers in the learning process (Dafik et al., 2023). Student worksheets are sheets containing assignments in which there are various kinds of questions to be implemented during instruction (Ekramipooya et al., 2024). However, student worksheets do not only contain questions but can also contain concepts that help students in learning materials. Student worksheets can be used to train students' creativity (Branch, 2009; Hobri, 2010; Wang & Wang, 2024). One of them is by using the PjBL learning model by using the PjBL learning model will be able to train students' creativity in the learning process (Eroğlu & Bektaş, 2022; Rati et al., 2023). So that researchers can develop mathematics learning media that can be used practically and effectively using *the research & development* method using one of the models, namely ADDIE. A review of 50 Publish or Perish-supported articles related to the development of PjBL-based electronic worksheets from 2017-2022 revealed several research gaps.

A literature search using *Publish or Perish* identified 50 publications on the use of Project-Based Learning (PjBL)-based worksheets to support creative thinking skills between 2017 and 2022. Two initial studies were published in 2017 (Nurjani, 2017), while no relevant works appeared in 2018. Research activity grew in 2019 with eight studies Kartika (2019), Permana (2019), Qonita (2019), Rahayu (2019), Sari (2019), dan Rasyid (2019), and further increased to 11 studies in 2020 (Astriani, 2020; Fauziah, 2020; Lismidarni, 2020; Natakusumawati, 2020; L. Sari et al., 2020; Sugihartono et al., 2020; Susilawati, 2020; Trimawati et al., 2020; Widya et al., 2020.). In 2021, 11 studies were published (e.g., Arsana & Sujana, 2021; Geacelyn et al., 2021; Handayani et al., 2021; Khotimatuzzahara et al., 2021; Mariati et al., 2021; Nana Misrochah, 2021; Nurmi et al., 2020; Setiawan & Indana, 2021; Tahapary et al., 2021), followed by a peak in 2022 with 13 studies, including those by Afrijhon et al., 2022; Dere et al., 2022; Rasyid, 2019; Ridha et al., 2022; Saputri & Herawati, 2022; T. P. Sari, 2022; N. R. Setiawan, 2022; Simamora et al., 2022; Syamsu et al., 2022.

This steady growth after 2019 reflects the increasing importance of PjBL and e-worksheets in education. It aligns with 21st-century learning demands, which emphasize creativity, innovation, collaboration, and global competitiveness (Bayley, 2022; Rofiq, 2022). Modern approaches such as inquiry-based tasks, design projects, and collaborative activities foster original thinking as a core competence of the 21st century (Darmuki et al., 2023; Supena et al., 2021; Taar & Palojoki, 2022; Yudistira, 2023).

Within this context, PjBL has been widely recognized as an effective model for cultivating creative thinking (Yudistira, 2023; Moust et al., 2021; Sucilestari et al., 2023; Wilkie, 2024). Its effectiveness, however, depends heavily on supporting tools. A key innovation is the PjBL-based e-worksheet, which not only structures learning activities but also provides conceptual scaffolding for deeper understanding (Ali & Xie, 2021; Hegarty & Waller, 2005; Mrazek et al., 2024). Recent evidence shows that such e-worksheets significantly enhance creative thinking indicators fluency, flexibility, originality, and elaboration (Yudistira, 2023; Wardani, 2024). Overall, the review of 50 studies underscores the potential of PjBL based e-worksheets to address the challenges of 21st-century education. Nevertheless, research gaps remain, particularly in terms of long-term effectiveness, integration with digital technologies, and the development of standardized instruments to comprehensively assess creative thinking skills.

Based on this background, previous studies have developed e-worksheets using inquiry, Problem-Based Learning (PBL), and Project-Based Learning (PjBL). These studies mainly focused on improving conceptual understanding and problem-solving skills but have not fully integrated project-based approaches with comprehensive measurement of creative thinking skills. This research fills that gap by introducing an innovative program called ProCreaMath, which synergizes interactive digital e-worksheets with PjBL to explicitly enhance creative thinking based on Torrance's framework (fluency, flexibility, originality, elaboration). The e-worksheet is developed adaptively and contextually through the ADDIE framework to ensure validity, practicality, and effectiveness in stimulating idea exploration through real-world projects. Therefore, this study aims to design and develop ProCreaMath to foster students' creative thinking skills in the digital era, particularly in learning the topic of nets of three-dimensional geometric shapes.

METHOD

This research uses the Research and Development (R&D) method with the aim of developing and testing the effectiveness of products in the form of (PjBL)-based Electronic Worksheets to achieve creative thinking skills of eighth grade odd semester Muhammadiyah 2 Kalasan Junior High School. The development model used is ADDIE (Analysis, Design, Development, Implementation, Evaluation), which was chosen because of its systematic nature and easy to implement in the development of teaching materials.

The Relationship between Sintak PjBL, Student Activities and Creative Thinking Skills

The Project-Based Learning (PjBL) learning model has characteristics that support the development of student creativity in learning. The main characteristics of PjBL include: first, students are given the opportunity to make decisions regarding the framework they will use. Second, there are problems or challenges that are submitted to students to be solved. Third, students design a process to find solutions to the problem. Fourth, students work collaboratively to access and manage the information needed in problem solving. Fifth, evaluations are carried out throughout the process to measure progress and success in resolving problems. Sixth, students periodically reflect on the activities that have been carried out. Seventh, the final product produced is evaluated qualitatively. Eighth, a learning situation that is tolerant of mistakes and changes allows students to be more creative (Aditya, 2025; Saimon, 2023).

PjBL emphasizes contextual-based learning with complex activities, which allows students to investigate and solve problems while producing real products. In this context, lecturers provide opportunities for students to work together in building their own knowledge, thereby increasing creativity and critical thinking skills (Torrance, 2018). Therefore, PjBL is very effective for the advancement of students divergent thinking skills, as this model facilitates the development of problem-solving, creative thinking, and collaborating skills with peers. In Geometry courses, especially point and line material, the application of PjBL is very relevant to increase students' creativity, because this model encourages them to think creatively in completing. Thus, PjBL is proven to be the right learning model to develop students' creative thinking skills in Figure 1.

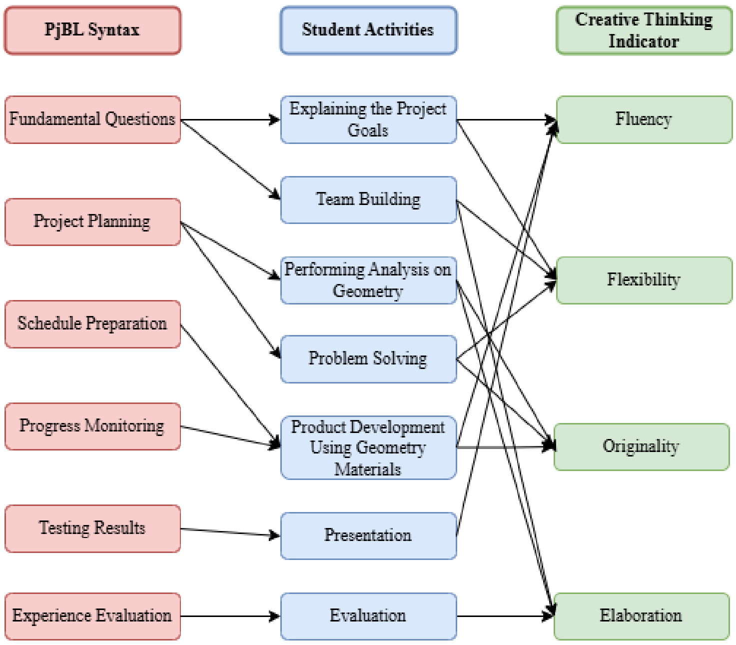


Figure 1. The Relationship between Sintak PjBL, Student Activities and Creative Thinking Skills

Research Prosedur

This study employed the ADDIE development model, which consists of five systematic stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). The analysis phase focused on identifying instructional needs, curriculum alignment, and learner characteristics to ensure the e-worksheet addressed relevant learning requirements. The design phase involved structuring the e-worksheet cover, table of contents, user guidelines, learning materials, and assessments on the principles of Project-Based Learning (PjBL) (Günzel & Brehm, 2024).

During the development phase, the e-worksheet was constructed and validated by content and media experts using assessment instruments. Revisions were made according to expert feedback to enhance content accuracy and media quality (Branch, 2009). The implementation phase began with small-group trials involving 4–5 students, followed by revisions and large-group trials to evaluate practicality and usability (Günzel & Brehm, 2024). Finally, the evaluation phase measured the product's validity, practicality, and effectiveness through expert validation, student response questionnaires, and creative thinking tests. In Figure 2 structured procedure ensured that the developed e-worksheet demonstrated high validity, practicality, and effectiveness in fostering students' creative thinking, particularly in fluency, flexibility, originality, and elaboration (Branch, 2009; Günzel & Brehm, 2024).

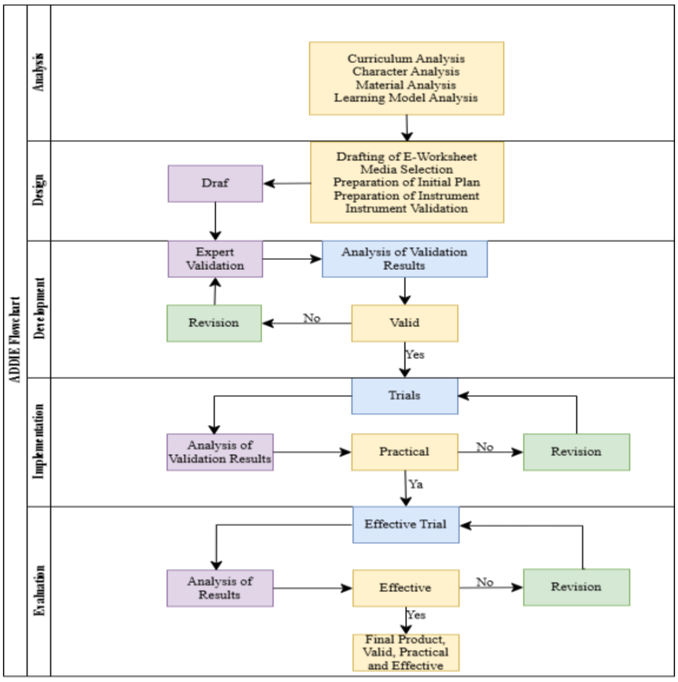


Figure 2. Research Porsedur

1. Data Sources and Research Subjects

Quantitative data was obtained from the e-worksheet analysis score by material and media experts, as well as student learning outcomes, while qualitative data was obtained from a validity test questionnaire and student response containing criticism and suggestions (Sugiono, 2019). Data sources are divided into primary data, which is obtained through interviews and questionnaires, and secondary data from relevant literature and documents. The research subjects consist of material and Muhammadiyah 2 Kalasan Junior High School Geometry course. Students are instructed to use the e-worksheet developed in Project-Based Learning (PjBL)-based learning, fill out a response questionnaire, and show the results of group creativity.

2. Data Collection Instruments

This study uses two main techniques in gathering of data, namely assessment and observation techniques. Non-test techniques include material expert validation sheets, media expert validation sheets, student response sheets, and documentation. The validation sheet of material experts and media experts was used to measure the validity of the e-worksheet developed, by referring to the guidelines set by the Ministry of National Education (2019) which have been adjusted to the needs of this research. The validation process is carried out by material and media experts to ensure that the e-worksheet is in accordance with academic standards and effective learning media. In addition, student response sheets were used to evaluate the practicality of Project-Based Learning (PjBL)-based e-worksheets by collecting feedback from students regarding the relevance of the material, language suitability, and quality of teaching delivered. Students are considered to give a positive response if their assessment of these three aspects shows good results. Meanwhile, documentation is used to collect visual data in the form of photos and images that illustrate students' creativity in using the e-worksheet. In addition, test techniques are used to measure students' understanding of geometry materials, especially on the topic of points and lines, as well as to measure the level of students' creativity in thinking through specially designed questions. All data obtained through these non-test and test techniques will be analysed in depth to provide a more complete picture of the effectiveness of using e-worksheets in mathematics learning.

3. Data Analysis Techniques

1) Product Validity Test

The information gathered form the material specialist questionnaire, media specialist's questionnaire, and student feedback questionnaire were utilized to assess the validity of the e-worksheet product (Widoyoko, 2009). The analysis process involves converting quantitative data into qualitative data based on predetermined criteria. Determine the average of the data that has been collected from the two validators using the formula.

$$\bar{X} = \frac{\sum_{i=1}^{n} \bar{x}_i}{n}$$

Then convert the obtained scores into qualitative data in accordance with the assessment criteria in Table 1. After validating the developed product is valid if it has the minimum criteria of good level (Widoyoko, 2009).

Table 1 Criteria for Quality, e-worksheet

Quantitative Score Range	**Criterion**
$\bar{x} > (\bar{x}_i + 1{,}8SB_i)$	Excellent
$(\bar{x}_i + 0{,}6SB_i) < \bar{x} \leq (\bar{x}_i + 1{,}8SB_i)$	Good
$(\bar{x}_i - 0{,}6SB_i) < \bar{x} \leq (\bar{x}_i + 0{,}6SB_i)$	Enough
$(\bar{x}_i - 1{,}8SB_i) < \bar{x} \leq (\bar{x}_i - 0{,}6SB_i)$	Less
$\bar{x} \leq (\bar{x}_i - 1{,}8SB_i)$	Very Less

2. Practicality Test Analysis

Analysis of the practicality test by evaluating student feedback on the use of e-worksheets that have been developed. The stages carried out are data tabulation, finding out the average score, converting scores as shown in Table 1 and analysing the quality of the e-worksheet.

3. Analysis of Effectiveness Tests

Analysis The e-worksheet effectiveness test was conducted to assess the extent to which the implementation of e-worksheets achieved the set goals (Widoyoko, 2009). According to Hobri (2010), learning tools can be said to be effective if students' responses to their use are good and at least ≥ 60% of students achieve Graduate Learning Outcomes (CPL). If it is less than 60%, then the device is considered ineffective with the formula and criteria for the effectiveness of using e-worksheets as shown in Table 2.

$$P = \frac{JP}{JS} \times 100\%$$

Table 2. Effectiveness Criteria e Worksheet

Value	Category
$P \geq 80\%$	Excellent
$60\% \leq P < 80\%$	good
$40\% \leq P < 60\%$	Pretty good
$20\% \leq P < 40\%$	Less good
$P < 20\%$	Very bad

In the kericer, the effectiveness of e-worksheet products can be assessed based on the results of student project work, if the minimum score is good, then the e-worksheet is considered effective (Widoyoko, 2009).

4. Creative Thinking Ability Analysis

The analysis of creative thinking skills was carried out by comparing the scores obtained by students with the maximum test score, multiplied by 100% (Widoyoko, 2009). The creative thinking score is calculated using the following formula in Table 3.

$$\text{Creative thinking skills } = \frac{\text{Score obtained}}{\text{Maximum score}} \times 100\%$$

Table 3. Criteria for Creative Thinking Ability

Value	Category
$P \geq 80\%$	Excellent
$60\% \leq P < 80\%$	good
$40\% \leq P < 60\%$	Pretty good
$20\% \leq P < 40\%$	Less good
$P < 20\%$	Very bad

If the learning outcomes reach the criteria of $61\% - 80\%$, it can be concluded that they have achieved the ability to think creatively as given in Table 3 (Widoyoko, 2009).

RESULTS AND DISCUSSION

A. Analysis

A review of 50 Publish or Perish-supported articles related to the development of PjBL-based electronic worksheets from 2017-2022 revealed several research gaps as shown in Table 1. First, most of the research was conducted at the primary and secondary education levels, while studies in universities were still limited as shown in Figure 3.

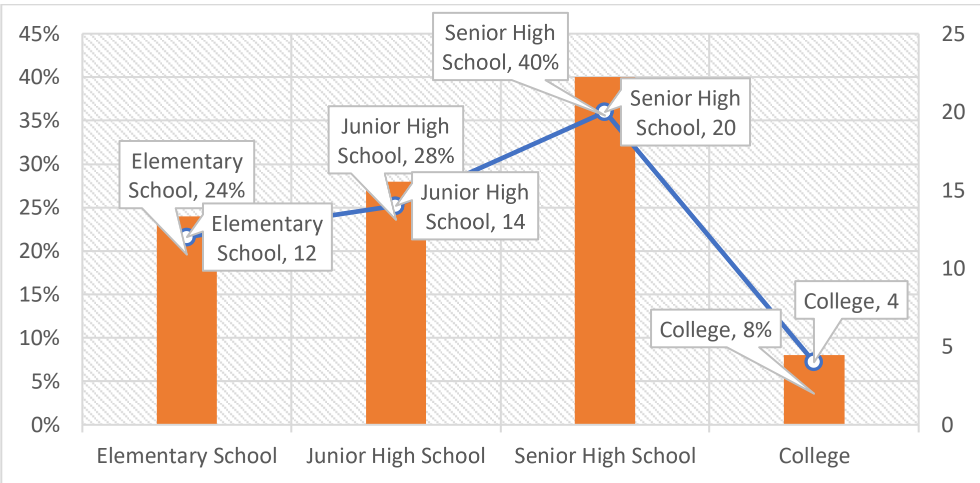


Figure 3. The Use of PjBL-Based Worksheets for Creative Thinking Skills

Second, the systematic use of the ADDIE development model in these studies is still rarely found as shown in Figure 4. Where the most used are ASSURE, 4D, Borg and Gall, 3D and the least used is ADDIE.

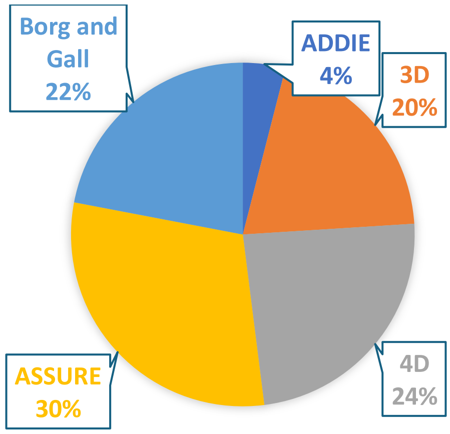


Figure 4. Development Model

Third, the focus of e-worksheet development still revolves around early courses such as basic statistics, linear algebra, analytical geometry, and trigonometry, while the topic of dimensional space geometry receives less attention as shown in Figure 5.

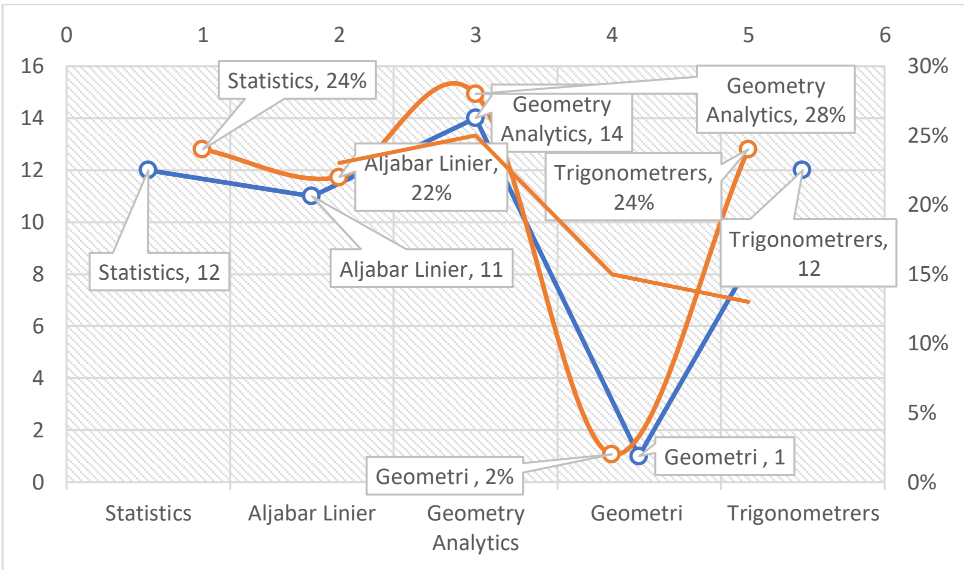


Figure 5. Materials Used

The needs analysis at Muhammadiyah 2 Kalasan Junior High School was carried out through interviews with teachers in mathematics. The results show the need to develop Project-Based Learning (PjBL)-based e-worksheets to improve students' creative thinking skills in flat side space building nets material. The learning media used so far is still limited to printed books and PowerPoint presentations (PPT). In the implementation of the Independent Learning Curriculum, students are required to study independently anytime and anywhere. Therefore, the development of digital-based e-worksheets is considered important to support the achievement of learning competencies.

The Spatial Geometry topic was selected as the focus of development because it serves as a foundation for understanding more complex geometry topics and is taught in the second semester. In accordance with the Independent Curriculum applied at Muhammadiyah 2 Kalasan Junior High School, the Minimum Mastery Criteria (KKM) is set at a score of 70. Learning objectives at the junior high school level include developing students' faith and character, creative thinking, and problem-solving skills through meaningful and contextual learning.

Based on interviews with teachers and classroom observations, although students generally understand the basic concepts, they still experience difficulties when constructing the nets of 3D shapes in various ways. Many students rely heavily on memorizing standard formulas and show limited creativity in solving geometry problems. Instructional strategies such as discussion and Problem-Based Learning (PBL) have not been fully optimized to stimulate student creativity.

Although the Project-Based Learning (PjBL) model aligns with the goals of the Independent Curriculum, it has not been implemented effectively due to limited learning media and time constraints. Additionally, some students show low enthusiasm and perceive Spatial Geometry as a challenging subject. Their creative thinking abilities remain underdeveloped, and many require structured guidance. This situation highlights the urgent need to develop PjBL-based digital learning media (such as an e-worksheet) to improve students' engagement, independence, and creative thinking skills in learning Spatial Geometry.

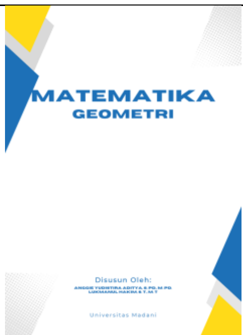
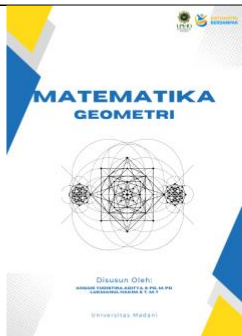
A. Design

The design stage begins with designing a PjBL-based e-worksheet using Adobe Illustrator and saved in PDF format. Each page that has been matched is then combined using the I Love PDF site, followed by editing through Flip Book Professional into an electronic book that can be accessed on various operating systems. Material references are collected to enrich the content of the e-worksheet. Furthermore, the learning steps are designed based on the PjBL syntax and the indicator of creative thinking ability. The researcher also compiled assessment instruments for validation by media experts, material experts, user responses, and post-test questions.

B. Development

PjBL-based e-worksheet products are developed and laid out using Adobe Illustrator, Microsoft Word and Flip Professional with content guidance and background color design, font size to the use of equation for writing each number and formula formula. The product results of each revision that have been developed are as Table 4.

Table 4. Development E-Worksheet

No	Revision Preview	Post-revision view
1.	 Cover before revision	 Cover after Revision
2.	 Contents Page Before Revision	 Contents Page After Revision

3.	 Backpage before revision	 Backpage after revision

The material in the learning media that has been validated by the validator is then accumulated in quantitative form. Each question item has an assessment of whether the learning media developed can be used or cannot be used. The following is the process of accumulating data that has been obtained from the validators of the material experts that have been given. The product developed is valid if it has the minimum criteria of a good level. The following criteria for the quality of the material in the e-worksheet can be seen in Table 5.

Presents the quality criteria of the e-worksheet based on the mean score ($\bar{x}$) obtained from the validation process. The classification into five categories *Excellent, Good, enough, Less,* and *Very Less* provides an objective benchmark for assessing product feasibility. An e-worksheet categorized as *Excellent* ($\bar{x} > 54.6$) indicates that it fully meets the required aspects of validity, practicality, and effectiveness, while scores in the *good* range ($44.2 < \bar{x} \leq 54.6$) suggest it is suitable for use with minor improvements. Lower categories (*Enough, Less,* and *Very Less*) highlight the need for more substantial revisions before classroom application. This quantitative validation ensures that only e-worksheets rated *Good* or *Excellent* are feasible for implementation and guides systematic revisions to enhance product quality.

Table 5. E-Worksheet Quality Criteria

Quantitative Score Range	**Criterion**
$\bar{x} > 54{,}6$	Excellent
$44{,}2 < \bar{x} \leq 54{,}6$	Good
$33{,}8 < \bar{x} \leq 44{,}2$	Enough
$23{,}4 < \bar{x} \leq 33{,}8$	Less
$\bar{x} \leq 23{,}4$	Very Less

In this process, validation is carried out quantitatively, namely by calculating the results of the values that have been given. The following results of data processing from the validation results of media experts provided by the validator can be seen. In table 6, it is explained that the score obtained in the validation of media experts is 55 in the first validator who stated that the media that has been created in the category is very good, and 53 in the second validator who states that the media that has been developed is in the good category. After that, accumulation is carried out in the form of the average score of the first and second validators resulting in a score of 54. Thus, it is concluded that the media that has been developed produces either a good category or a valid category. Table 6 shows that Validator I gave a score of 55 (*Excellent*), while Validator II provided a score of 53 (*Good*), resulting in an average score of 54 categorized as *Good*. Referring to the quality criteria in Table 5, this result indicates that the developed e-worksheet is valid and feasible for implementation in the learning process, with minor revisions suggested to optimize its quality.

Table 6. Media Expert Validation Results

Validator	Total Score	Category
Validator I	55	Excellent
Validator II	53	Good
Sum	108	
Average	54	Good

Furthermore, a validation analysis of meter experts was carried out by two validators The material on the learning media that had been validated by the validator was then accumulated in quantitative form. Each question item has an assessment of whether the learning media developed can be used or cannot be used. The following is the process of accumulating data that has been obtained from the validators of the material experts that have been given. The product developed is valid if it has the minimum criteria of a good level. The following criteria for the quality of material in e-worksheet can be seen in Table 8.

The validation results from material experts (Table 7) showed that the developed e-worksheet was categorized as *Good*, indicating that the content is relevant, accurate, and aligned with the learning objectives. This finding is consistent with Widoyoko (2009) view that a valid Branch (2009) learning product must fulfill content and construct validity and supports statement that expert validation is crucial in ensuring product quality in educational development. Similar results were also reported by Günzel & Brehm (2024), who found that e-worksheets in the *good* category were already feasible for classroom implementation with minor revisions. The criteria for quantitative validation used in this study were adapted from Sugiono (2020), which classifies product quality into several levels ranging from *Very Less* to *Excellent*. Thus, the ProCreaMath e-worksheet developed in this study can be considered valid and ready for use, while minor refinements are recommended to optimize its quality.

Table 7. Quality Criteria for E-Worksheet Materials

Quantitative Score Range	Criterion
$\bar{x} > 67{,}2$	Excellent
$54{,}4 < \bar{x} \leq 67{,}2$	Good
$41{,}6 < \bar{x} \leq 54{,}4$	Enough
$28{,}8 < \bar{x} \leq 41{,}6$	Less
$\bar{x} \leq 28{,}8$	Very Less

Table 7 is a reference in carrying out the criteria resulting from the validation of the material used in the e-worksheet. Next, calculations were carried out to determine whether the material used in the category was good or not to be seen. Table 8 shows that Validator I rated the e-worksheet material with a score of 64 (*Good*), while Validator II gave 70 (*Excellent*), resulting in an average score of 67 categorized as *Good*. This indicates that the material is valid, accurate, and aligned with learning objectives, although minor improvements are still needed. The result is consistent with Widoyoko (2009) view that validity is achieved when content, construct, and language aspects are fulfilled, and in line with Branch (2009) emphasis on expert validation in educational development. Similar findings were reported by Susanti (2021), who showed that e-worksheets in the good category are feasible for classroom implementation. The criteria used to determine this classification were adapted from Günzel & Brehm (2024), confirming that the ProCreaMath e-worksheet is valid and ready to proceed to the implementation stage.

Table 8. Results of Material Expert Validation

Validator	Total Score	Category
Validator I	64	Good
Validator II	70	Excellent
Average	67	Good

In table 8, it is explained that each validator assessment used in this study results in a good category in the first validator, namely achieving a score and having results in the very good category in the second validator, namely achieving a score. Then the next step is to accumulate which is done by looking for the average score of the two validators. In accumulating the validation results carried out, an average of 67 is in the good category. So that the material used is suitable for use in research and can be carried out in the next step, namely the implementation stage.

C. Implementation

After validating the resulting product so that it can be suitable for use. The researcher then tested PjBL-based e-worksheets to achieve students' creative thinking skills. This test was carried out to determine the quality of the e-worksheet from a practical aspect. The step taken was to use a large class of 26 students in the odd semester. The implementation of this implementation is conveyed in learning using e-worksheets in learning activities. So that in learning the geometry of the space material of the flat side space building nets, students can use the e-worksheet that has been developed.

The learning activities carried out have been adjusted to the PjBL syntax on the e-worksheet (Widoyoko, 2009). So that each student in a group uses the e-worksheet in learning activities. The last step is for students to fill out a user response questionnaire to assess the practicality of the product. The following practical criteria that have been adjusted can be seen in Table 9.

Table 9. Practicality Criteria

Quantitative Score Range	Criterion
$\bar{x} > 67{,}2$	Excellent
$54{,}4 < \bar{x} \leq 67{,}2$	Good
$41{,}6 < \bar{x} \leq 54{,}4$	Enough
$28{,}8 < \bar{x} \leq 41{,}6$	Less
$\bar{x} \leq 28{,}8$	Very Less

The results obtained were carried out by distributing a questionnaire of user responses to the use of e-worksheets that have been developed. So that we get accurate results in the use of e-worksheets that have been developed. Furthermore, from the results of the quantitative practicality assessment data from user responses, it can be seen. Table 10 shows that the user response to the developed e-worksheet reached an average score of 75.6, categorized as *Excellent*. This result indicates that the e-worksheet is highly practical and well received by students, as most responses were in the *Excellent* range with only a few in the good category. According to Branch (2009), practicality is achieved when learning media can be easily used in real settings, and this finding is consistent with previous studies (Aditya, 2024; Koo & Lee, 2021; Sari, 2019; Wardani, 2021; Wilkie, 2024) which also reported that interactive e-worksheets were perceived as practical in supporting active learning. Referring to the criteria adapted from Sugiono (2020), the score obtained confirms that the ProCreaMath e-worksheet meets the minimum requirements for practicality and is feasible for implementation in the learning process.

Table 10. User Response Score Results

Respond	Skor	Criterion
S1	78	Excellent
S2	80	Excellent
S3	60	Good
S4	75	Excellent
S5	80	Excellent
S6	80	Excellent
S7	78	Excellent
S8	80	Excellent
S9	80	Excellent
S10	78	Excellent
S11	78	Excellent
S12	71	Excellent
S13	78	Excellent
S14	78	Excellent
S15	80	Excellent
S16	80	Excellent
S17	73	Excellent
S18	70	Excellent
S19	62	Good
S20	76	Excellent

S21	70	Excellent
S22	71	Excellent
S23	70	Excellent
S24	80	Excellent
S25	79	Excellent
S26	80	Excellent
Average	75,6	Excellent

In the trial carried out, the results of the user response questionnaire were obtained with an average of 75.6 with very good criteria. So, it can be said that e-worksheets can be declared practical. A good e-worksheet is with a minimum of good criteria so that it can be used properly and can increase student activities. The following results of professionalism in each aspect can be seen in Picture 6.

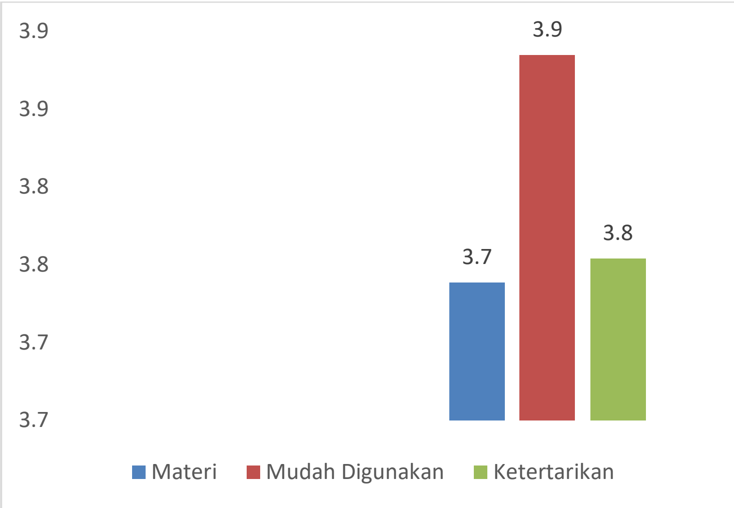


Figure 6. Average User Response Results for Each Aspect

Figure 6 illustrates that among the three aspects assessed, the *easy-to-use* dimension scored the highest (3.9), followed by *interest* (3.8) and *material* (3.7). The prominence of the *easy-to-use* aspect demonstrates that the design of the ProCreaMath e-worksheet successfully integrates user-friendly features such as intuitive navigation, clear instructions, and adaptive formatting. These elements are essential for ensuring practicality, as emphasized by Branch (2009), who stated that practicality is achieved when media can be implemented without significant barriers in real learning contexts. The high usability score suggests that students can interact with the e-worksheet independently, reducing reliance on external guidance, and allowing them to focus on project-based tasks more effectively.

The *interest* aspect, with a high score of 3.8, reflects that the e-worksheet is not only functional but also appealing to learners. This result is consistent with findings from Nasution (2017), who highlighted that interactive and visually engaging media stimulate student motivation and sustain learning activities. Similarly, Hadar & Tirosh (2019) reported that digital worksheets incorporating real-life problems foster greater student involvement and curiosity. The appeal of the ProCreaMath e-worksheet lies in its contextualized project tasks, which connect mathematical concepts to real-world applications, thereby making learning more meaningful.

Meanwhile, the *material* aspect (3.7) also received a high score, indicating that the content of the e-worksheet is clear, accurate, and aligned with learning objectives. Although slightly lower than the other aspects, this still meets the criteria of validity and supports conceptual understanding. This aligns with Branch (2009), who emphasized that expert-validated instructional content is essential for ensuring media effectiveness. Previous research (Hadar & Tirosh, 2019; Nasution et al., 2017) has shown similar findings, where well-structured e-worksheets in the *Good* to *Excellent* range were able to improve students' learning outcomes. Overall, the consistently high scores across all aspects affirm that the ProCreaMath e-worksheet meets the criteria of practicality, being not only easy to use but also interesting and supported by relevant material. This suggests that the product is feasible for implementation and has strong potential to promote active, project-based learning while enhancing students' creative thinking skills in mathematics.

D. Evaluation

Furthermore, it is carried out on the effectiveness of the product which is carried out with a test to measure the achievement of students' creative thinking skills. The results of the learning supervision are used to determine student learning outcomes in learning using e-worksheets. In Table 12, it is known that student learning outcomes with an average of 88.5. Based on Table 2, the effectiveness criteria of the e-worksheet that have been determined result in the learning media that have been developed in the category are very good. This is shown by the known category in table 12 with a result of 88.5 ≥ 80. The following is a calculation of the completeness of each student's learning outcomes after using the e-worksheet.

The findings indicate that out of 26 learning outcomes assessed, 15 achieved a score of 100 and 11 obtained a score of 75, resulting in an aggregate mean of 89.42. This score is well above the minimum mastery threshold (≈75), suggesting that, in general, the learning outcomes fall into the *Surpass* category. Such achievement reflects the effectiveness of the instructional design and its implementation in supporting competency mastery.

The high level of attainment can be explained by the alignment among learning objectives, instructional activities, and assessment instruments. The principle of *constructive alignment* (Hopper, 2014; Stehling & Munzert, 2018; Van Hooijdonk et al., 2022) emphasizes that learning outcomes are more likely to be achieved when objectives, activities, and assessments are coherently aligned. This alignment provides students with clear opportunities to demonstrate competencies according to the predetermined indicators.

Furthermore, the success of these outcomes can also be attributed to the application of project-based learning (PjBL) strategies and the use of e-worksheet media. Several meta-analyses have shown that PjBL contributes positively to academic achievement, critical thinking, and student motivation (Aditya, 2025; Saimon, 2023). Likewise, research on e-worksheets has demonstrated that interactive digital teaching materials can enhance learning efficiency, participation, and students' critical thinking skills (Eroğlu & Bektaş, 2022; Rati et al., 2023). These findings are consistent with the high-performance pattern observed in this study in Table 11.

$$P = \frac{JP}{JS} \times 100\%$$

$$P = \frac{26}{26} \times 100\%$$

$$P = 100\%$$

Table 11. Student Learning Outcomes

No	Name	Learning Outcomes	Information
1.	S1	100	Surpass
2.	S2	100	Surpass
3.	S3	100	Surpass
4.	S4	100	Surpass
5.	S5	75	Surpass
6.	S6	75	Surpass
7.	S7	100	Surpass
8.	S8	75	Surpass
9.	S9	75	Surpass
10.	S10	100	Surpass

No	Name	Learning Outcomes	Information
11.	S11	100	Surpass
12.	S12	100	Surpass
13.	S13	100	Surpass
14.	S14	100	Surpass
15.	S15	75	Surpass
16.	S16	75	Surpass
17.	S17	75	Surpass
18.	S18	75	Surpass
19.	S19	75	Surpass
20.	S20	100	Surpass
21.	S21	100	Surpass
22.	S22	100	Surpass
23.	S23	100	Surpass
24.	S24	75	Surpass
25.	S25	75	Surpass
26.	S26	100	Surpass
Average		88,5	Surpass

The outcomes of the innovative cognitive evaluation are utilized to assess the proficiency of students' creative thought capabilities. The subsequent fiding regarding creative thinking abilities can be found. The results in Table 12 indicate that students' creative thinking skills overall fall into the Highly Creative category, with an average achievement of 89.42%. This finding demonstrates that the applied learning design, particularly through the integration of Project-Based Learning (PjBL) with digital e-worksheets, is effective in fostering students' creativity. The high percentage of students reaching the Highly Creative category (100% score) further highlights the success of this approach in enhancing fluency, flexibility, originality, and elaboration, which are the main dimensions of creative thinking as defined by (Torrance, 2018).

The consistency of students achieving perfect scores (e.g., S1, S2, S3, and others) suggests that the implemented learning strategy not only increases cognitive engagement but also provides opportunities for students to explore and express diverse problem-solving ideas. This aligns with the study of Ekramipooya (2024), which emphasizes that learning environments supporting autonomy, collaboration, and digital interactivity can strengthen the development of creative thinking skills. Meanwhile, students who fall under the Creative category (75%) still demonstrate strong performance, though the results suggest the need for additional guidance to optimize their originality and elaboration.

These findings are consistent with previous studies, such as Alabbasi (2022), who reported that the integration of Project-Based Learning with digital resources can enhance students' creative problem-solving skills in mathematics. Similarly, (Cassotti et al., 2016; Kaur et al., 2021) asserted that interactively designed digital platforms can create meaningful learning experiences that stimulate higher-order thinking processes. This study reinforces such insights by showing that the synergy between PjBL and e-worksheets enables students to actively construct knowledge, collaborate, and generate creative outputs.

From a pedagogical perspective, these findings affirm that creative thinking skills can be effectively nurtured when learning activities are contextualized and supported with appropriate technological tools. The fact that the average score is close to the maximum criteria underscores the importance of learning designs that encourage exploration rather than rote memorization. Furthermore, the achievement reflects the relevance of constructivist theory, which posits that knowledge construction is optimized when learners are provided with opportunities to create, reflect, and innovate in meaningful contexts (Lee et al., 2024; Zen et al., 2022).

Thus, it can be concluded that the implementation of Project-Based Learning supported by e-worksheets is an effective approach for enhancing creative thinking skills. However, attention should also be directed toward students in the Creative category by providing more targeted tasks and continuous feedback to maximize their potential. This comprehensive evaluation not only validates the effectiveness of the learning design but also provides valuable references for future instructional strategies in fostering creativity in mathematics education.

Table 12. Results of Creative Thinking Ability

No	Name	Value	Percentage	Criterion
1	S1	100	100%	Very Creative
2	S2	100	100%	Very Creative
3	S3	100	100%	Very Creative
4	S4	100	100%	Very Creative
5	S5	75	75%	Creative
6	S6	75	75%	Creative
7	S7	100	100%	Very Creative
8	S8	75	75%	Creative
9	S9	75	75%	Creative
10	S10	100	100%	Very Creative
11	S11	100	100%	Very Creative
12	S12	100	100%	Very Creative
13	S13	100	100%	Very Creative
14	S14	100	100%	Very Creative
15	S15	75	75%	Creative
16	S16	75	75%	Creative
17	S17	75	75%	Creative
18	S18	75	75%	Creative
19	S19	75	75%	Creative
20	S20	100	100%	Very Creative
21	S21	100	100%	Very Creative
22	S22	100	100%	Very Creative
23	S23	100	100%	Very Creative
24	S24	75	75%	Creative
25	S25	75	75%	Creative
26	S26	100	100%	Very Creative
Average		89,423	89%	Very Creative

It was explained that in the criteria it was very creative. Based on Table 13 criteria for creative thinking ability. The results obtained are in the very creative category, this is aimed at the average achievement of students' creative thinking skills reaching 89%.

The results of the analysis that have been carried out have resulted in some students who have not achieved in each indicator. The highest percentage is found in *the fluency* and *originality indicators* with the percentage of. Followed by elaboration with percentages and flexibility. The reason why the indicators of flexibility 73% and *elaboration* 77% is lower than *fluency* 100% and *originality* 100%. This happens because students are only focused on completing answers in the same way. In line with the statement (Islami et al., 2018) states that students' focus is only focused on the same way and students are still lacking in self-discipline to do problems. So that in solving the questions that have been given, it takes longer and runs out of time to work on the questions.

In Figure 7 analysis indicate that students' creative thinking abilities vary across the four measured indicators: fluency, flexibility, elaboration, and originality. The findings reveal that the highest achievements were obtained in fluency (100%) and originality (100%), where all students were able to generate relevant ideas and provide original solutions. This suggests that students possess strong abilities in producing multiple answers while also demonstrating novelty in their problem-solving approaches. These results are consistent with Torrance (2018), who emphasized that fluency and originality are fundamental components of creativity.

However, lower percentages were observed in flexibility (73%) and elaboration (77%) compared to fluency and originality. This indicates that although students are capable of generating ideas, they tend to rely on similar strategies and face difficulties in shifting perspectives or developing answers in greater detail. Islami (2018) also highlighted that students often focus on a single method of problem-solving, which limits their flexibility in thinking. The lower achievement in elaboration may also stem from a lack of self-discipline and time management, as students require more time to expand and refine their responses.

The relatively lower performance in flexibility and elaboration further suggests that students are still in the process of developing higher-order creative thinking skills. While they can generate ideas, they struggle to enrich strategies and provide more in-depth explanations. According to (Cassotti et al., 2016; Kaur et al., 2021), the development of flexibility and elaboration requires instructional strategies that encourage open exploration, scaffolding, and opportunities to practice solving a variety of problems.

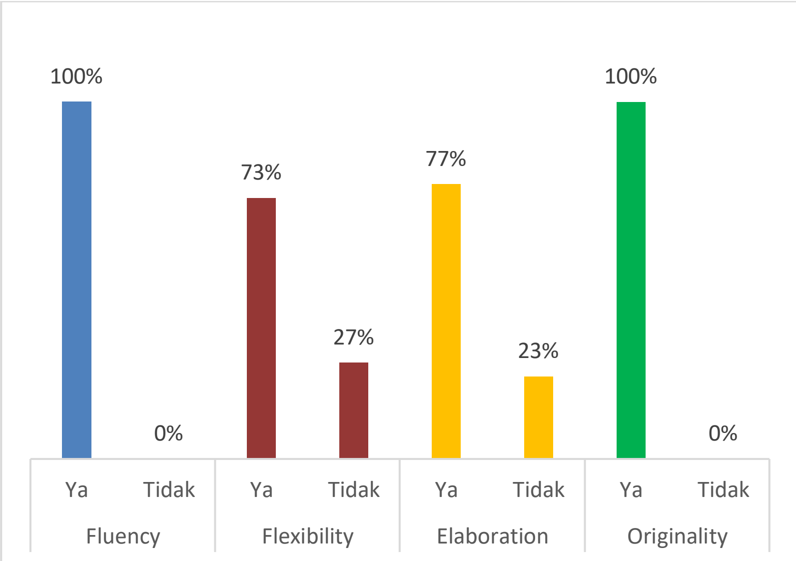


Figure 7. Results of Creative Thinking Ability

The following are the results of the analysis of each question that has been done through the creative thinking ability test from question No. 1 with the question A block has volume and width, look for possibilities from the length, width and height of the beam's ribs of at least 2 sizes! $400cm^2 5cm$ in Figure 8.

From the student's answer, it can be seen in Figure 8 that students have been careful in answering the questions that have been explained, namely answering 2 ways. In the *fluency* indicator, the average student reached. This happens because students are able to identify problems well 100% (OECD, 2019; Suherman & Vidákovich, 2022). Thus, it can be inferred that learners are capable of the responding to inquiries accurately.

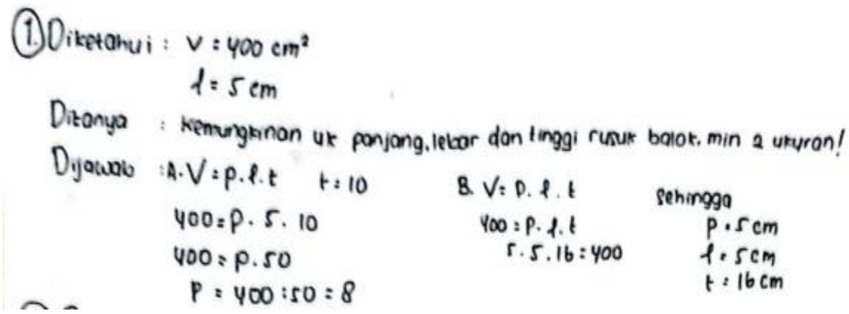


Figure 8. Answer No 1 S8 Student

Question number 2 It is known that cube A and B. Cube B can be filled by several cubes A. If the volume ratio of two cubes A and cube B is, then determine how many cubes A are needed to fill cube B! if there is space left, then how much space is left in cube B?23: 7

The answer of the s8 student in figure 9 is explained that the s8 students are very good at doing. The student calculates each building room A and B. So, in the student *flexibility* indicator reaches the average. In the 73%*flexibility indicator* with an average, it is included in the good category 73%. In the work, many students answered correctly and according to the desired results. This indicates that the student was able to adapt strategies appropriately in problem-solving. Moreover, many students provided correct answers that aligned with the expected outcomes.

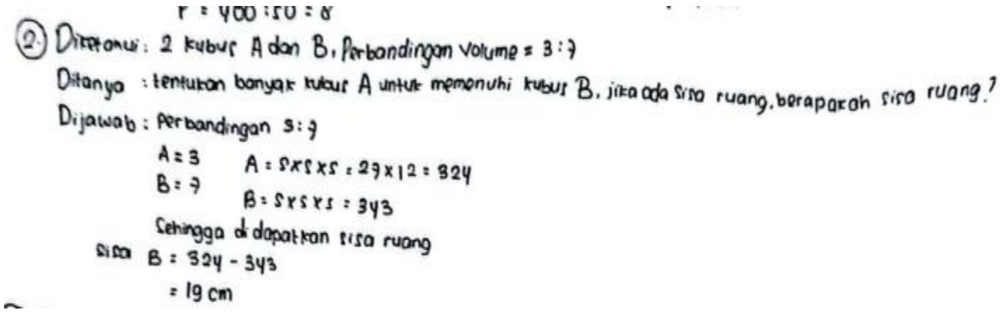


Figure 9. Answer to question no 2 S8 students

Question number 3, Explain in detail how to calculate a square prism surface area of the ABCD panajang square. EFGH if the rectangular prism has a height of 4cm, rib length AB=6cm, BC=4cm, CG=3cm, and TF=5cm! Figure 10, it is explained that students can answer question number 3. This shows that students are successful in answering questions well. In the indicator of student *elaboration* questions reached an average. In 77% *the elaboration,* students are able to develop new ideas in working on problems (Green et al., 2024; Suherman & Vidákovich, 2024). So that question number 3 indicates that students can answer question number 3 correctly.

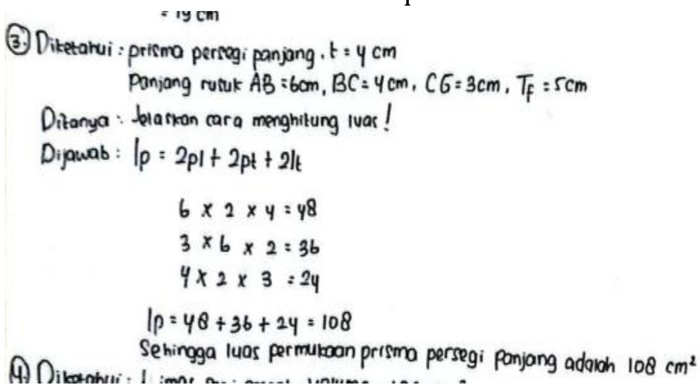


Figure 10. Answer to question no 3 S8 students

Question number 4 asks students to determine the length, width, and height of a cube with a known volume of 192 cm^3 and then calculate its surface area. Based on Figure 10, students were able to solve the problem correctly by applying the appropriate formulas and performing accurate calculations. In terms of the originality indicator, students achieved an average score of 100%. This indicates that students were able to find a unique yet correct solution path while also demonstrating a solid understanding of the relationship between volume and surface area in geometry.

When linked to other creative thinking indicators, these results further highlight students' strengths. From the perspective of fluency, most students were able to produce correct and consistent answers, although without much variation in the steps taken. In terms of flexibility, the problem itself did not provide much space for alternative solution strategies, which led to relatively uniform answers. Meanwhile, regarding elaboration, students displayed accuracy in writing down the steps and formulas used, even though the task did not require lengthy explanations beyond procedural accuracy.

The high achievement in the originality indicator reinforces the findings of previous studies (Nufus et al., 2024; Wilkie, 2024), which suggest that students tend to excel in structured and well-defined mathematical problems but still face challenges when dealing with open-ended tasks that demand more varied strategies. Thus, it can be concluded that students' ability to solve question number 4 is relatively high, reflecting their competence in applying mathematical concepts to structured tasks. At the same time, it also points to the need for further development of tasks that demand flexibility and elaboration. The development of the PjBL-based e-worksheet showed valid, practical, and effective results in improving students' creative thinking skills. The validation results from both media and material experts indicated a high-quality product. Furthermore, implementation in classroom learning showed strong student engagement and excellent feedback, while evaluation results revealed a significant increase in creative thinking outcomes.

Implications

The findings indicate that implementing PjBL-based e-worksheets significantly enhances students' creative thinking skills in Spatial Geometry, particularly in flat side space building nets. This suggests that integrating digital learning media with project-based learning can improve students' fluency, originality, flexibility, and elaboration in problem-solving. The results underscore the potential of combining technology with active learning strategies to foster higher-order thinking, aligning with 21st-century learning competencies. Furthermore, the study highlights the value of contextualized and interactive learning materials in promoting students' autonomy, engagement, and creative performance in mathematics.

Limitations

This study has several limitations. First, it was conducted in a single junior high school (SMP Muhammadiyah 2 Kalasan) with a small sample of 26 students, which may limit the generalizability of the findings. Second, the research focused exclusively on the topic of Spatial Geometry of flat side space building nets, so results may not reflect the effectiveness of e-worksheets across other mathematical topics. Third, creative thinking was assessed primarily through short-term post-tests, potentially overlooking long-term retention and application. These limitations suggest caution in generalizing the findings and highlight directions for future research.

Suggestions

Future studies should implement PjBL-based e-worksheets with larger and more diverse samples across various schools and educational levels. Researchers could also investigate their integration with other mathematical topics to evaluate broader effectiveness in enhancing creative thinking. Longitudinal studies are recommended to assess the sustainability and long-term impact on students' creative thinking and problem-solving abilities. Practitioners may adopt PjBL-based e-worksheets in classroom settings while providing structured guidance to optimize students' flexibility and elaboration skills.

CONCLUSION

This study aimed to develop a Project-Based Learning (PjBL)-based e-worksheet to enhance students' creative thinking skills in geometry, particularly on the topic of flat side space building nets at Muhammadiyah 2 Kalasan Junior High School. The product was developed using the ADDIE model and supported by digital tools such as Adobe Illustrator, Microsoft Word, and Flip PDF Professional. The findings indicate that the resulting e-worksheet meets the criteria of validity based on expert judgment, practicality with a user response score of 75.6, and effectiveness as evidenced by post-test results and students' learning completeness. These results highlight the importance of integrating PjBL with digital media to foster creative thinking skills while strengthening 21st-century competencies in mathematics education. Further research is recommended to expand the implementation of this media to other mathematical topics, different educational levels, and larger populations to improve its generalizability and impact. Therefore, the PjBL-based e-worksheet developed in this study can be concluded as an innovative, valid, practical, and effective learning tool to support students' creative thinking skills.

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AUTHOR CONTRIBUTIONS STATEMENT

AYA conducted needs analysis, designed the e-worksheet, developed the media, implemented the learning intervention, and evaluated the results. LH contributed to expert validation of the e-worksheet and provided input on pedagogical aspects. All authors reviewed and approved the final version of the manuscript.

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