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STUDENT CREATIVITY IN STEAM LEARNING THROUGH A POP-UP BOOK PROJECT BASED ON THE ENGINEERING DESIGN PROCESS

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ABSTRACT
This study aims to describe students' creativity in STEAM learning through a pop-up book project based on the Engineering Design Process (EDP) in mathematics education, viewed from the aspects of originality, flexibility, and elaboration. This study employs a descriptive qualitative approach. The research subjects consisted of three ninth-grade students selected through purposive sampling and categorized into high, medium, and low groups based on prior achievement. Data were collected through observation, interviews, documentation, and product analysis. Data were analyzed using the Miles and Huberman model, including data collection, data reduction, data presentation, as well as drawing conclusions and verification. The results show that STEAM learning integrated with the EDP stages provides meaningful learning experiences and supports the development of students' creativity. High-performing students demonstrated strong abilities in originality, flexibility, and elaboration compared to students in other categories. Moderate-performing students showed fairly good creativity but tended to rely existing ideas. Meanwhile, low-performing students showed limitations in generating original ideas, adapting designs, and developing products in detail. The findings also indicate that the Ask and Imagine stages facilitate idea exploration, the Plan and Create stages encourage problem-solving, and the Improve stage promotes reflection on and product refinement. Overall, the STEAM-based pop-up book project enhances the students' understanding of mathematical concepts through hands-on activities while fostering creativity across disciplines.

INTRODUCTION

Life in the 21st century demands that students possess more complex skills than merely mastering factual knowledge. Students must be able to think critically, creatively, collaborate, and communicate effectively in diverse situations. This aligns with the view of Putri *et al.* (2024), who state that 21st-century learning emphasizes the development of skills relevant to future needs, such as critical thinking, creativity, collaboration, and digital literacy.

One of the key components of 21st-century learning is creativity. Creativity extends beyond the arts and involves the ability to generate new ideas, solve problems innovatively, and present meaningful solutions. According

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to Famawati (2022), creativity is an activity and the ability to create something new or combine existing elements into something new that is meaningful and beneficial. Creativity, according to Fourniyati & Ariyatun (2022), refers to the creation of works, products, or solutions to problems in life. Indicators of student creativity, according to Munandar (Nurmala, *et.al,* 2021), include the ability to think fluently (fluency), the ability to think flexibly (flexibility), the ability to think originally (originality), and the ability to elaborate (elaboration).

In line with 21st-century learning, which emphasizes the 4Cs—critical thinking, collaboration, creativity, and communication—where these skills are collectively known as the 4Cs (Sapitri *et al.,* 2022), a curriculum is required to effectively facilitate the development of these competencies. The Merdeka Curriculum is one such curriculum that has emerged as a new paradigm in Indonesian education. According to Darmawan and Winataputra (Tuerah & Tuerah, 2023), the Merdeka Curriculum seeks to strengthen student autonomy and facilitate student-centered learning by emphasizing empowerment and the development of 21st-century skills.

Creativity is one of the eight dimensions of the graduate profile in the Merdeka Curriculum; it is a key competency that must be developed during the learning process. In the official document **Academic Paper on Deep Learning Toward Quality Education for All** (Ministry of Education, Culture, Research, and Technology, 2025), the creativity dimension within the 8-dimensional graduate profile of the Merdeka Curriculum refers to individuals capable of thinking innovatively, flexibly, and originally when processing ideas or information to create unique and beneficial solutions. In mathematics, creativity can emerge when students create diverse problem-solving strategies, build visual representations, or construct concrete models of an abstract idea.

Based on the school's educational report card data, the school's score for the creativity character indicator was 56.37, indicating that the composite score for students' creativity—based on their willingness to think differently, apply new ideas to solve problems, and create new works—remains relatively low. Based on the results of initial observations, it was also found that mathematics instruction tends to be monotonous, relying primarily on lectures, problem-solving exercises, and minimal use of concrete learning materials. Students are rarely assigned project-based tasks involving the creation of tangible products. Interviews with several students also revealed that students rarely engage in *hands-on* activities during learning, particularly in mathematics instruction. This ultimately results in low student engagement in the teaching-learning process and limited development of student creativity.

One of the learning approaches used to enhance student creativity is STEAM education (Science, Technology, Engineering, Art, and Mathematics). In STEAM-based learning, students are encouraged to integrate knowledge from various fields to solve problems collaboratively and creatively. A literature review by Susilowati, *et al.* (2025) concluded that STEAM enhances students' creativity, critical thinking, and collaboration skills. The integration of art into STEM adds value to learning, making it more contextual and meaningful. This approach aligns with the view that STEAM learning integrates problem-solving and design processes that support students' creative thinking and conceptual understanding (English, 2016). Therefore, to systematically facilitate these processes, STEAM learning in this study is integrated with the Engineering Design Process (EDP) model. The Engineering Design Process (EDP), as defined by Accreditation Board for Engineering and Technology (ABET), refers to the process of designing systems or component to meet specific needs (Yolida, *et al., 2025*). The steps of the EDP according to Hester & Cunningham (2007) are as follows:

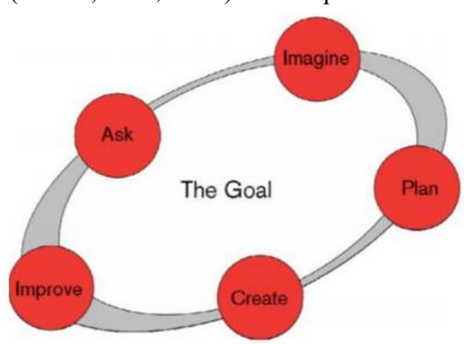

Figure 1. Engineering Design Process (EDP)

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(Source: Hester & Cunningham, 2007)

The EDP steps include Ask, Imagine, Plan, Create, and Improve. In the Ask step, identify the problem at hand, what others have done regarding the same problem, and what the constraints are. In the Imagine step, once the problem has been identified, create a list of potential solutions, brainstorm ideas at this stage, and then select the best idea. The next step is Plan. Plan the selected idea by drawing diagrams, tables, or graphs and listing the materials and tools required. Next, move on to the Create step. In this step, implement the plan you've developed as a solution, then test that solution. The final step is Improve, which involves evaluating and reflecting on the results of the tested solution.

To enhance students' creativity in mathematics learning, in addition to STEAM education, concrete learning materials can also be utilized. Previous studies have shown that innovative learning approaches involving concrete visual media and project-based exploratory activities can enhance students' critical thinking and creativity. According to Ompusunggu's (2022) research, the use of learning media facilitates teachers in the teaching-learning process, particularly in mathematics—a subject often disliked by students. Learning media serve an important function: they foster interest, alleviate boredom, and help students achieve active and productive learning goals (Yuwono et al. in Utari and Setyadi, 2023). One type of mathematics learning medium that can be used is the pop-up book, a learning medium in the form of a book with folds that, when opened, reveal material with a three-dimensional effect.

According to Bluemel and Taylor (Dewanti et al., 2018), the use of pop-up books as a learning medium is useful for: (1) fostering children's love of books and reading, (2) cultivating critical thinking and developing creativity, (3) conveying meaning through engaging visual representations, and stimulating a desire and motivation to read. In mathematics education, pop-up books are still rarely used, even though they are entertaining, engaging, and informal, making it easier for students to understand abstract concepts such as those found in mathematics lessons. Tactile, three-dimensional visualizations that can be directly touched and manipulated allow students to see the real-world connections between the elements of three-dimensional shapes, thereby strengthening their conceptual understanding. Furthermore, having students create pop-up books opens opportunities to foster their creativity. In designing and constructing pop-up books, students are challenged to think creatively to transform symbolic forms into visually appealing and meaningful representations. Students also learn to make decisions regarding the selection of shapes, colors, folding mechanisms, and the presentation of content through pop-up books in an engaging manner. This aligns with research conducted by Indrianti and Saputri (2025), which concluded that *using pop-up books* makes students happy and enthusiastic about learning, thereby enhancing their creativity.

Several previous studies have shown that STEAM-related learning can enhance students' creativity in the learning process, for example in the research by Ujwalita A. and Suryandari, K.C. (2026), Prahartiwi *et al.* (*2025*), and Puspitaningtyas *et al.* (2025). Other studies also demonstrate the effectiveness of the Engineering Design Process (EDP) in fostering 21st-century skills, as seen in the research by Nusyirwan *et al.* (2021) and Sartika, E. and Kau, M. U. (2025). Although most previous studies indicate that STEAM and EDP can enhance student creativity, the majority still focus on quantitatively measuring improvements in learning outcomes or creativity. Study that explore how student creativity develops in learning, particularly in EDP-based STEAM learning through pop-up book projects remains limited, particularly at the junior high school level. Based on this research gap, this study aims to describe students' creativity in STEAM learning through an EDP-based pop-up book project, focusing on originality, flexibility, and elaboration.

METHOD

This study employs a descriptive qualitative approach. The study aims to understand the phenomena experienced by the research subjects through description within a specific context. In this study, qualitative research is used to understand and describe students' creativity in STEAM learning through the implementation of a pop-up book project based on the Engineering Design Process (EDP) in mathematics instruction. Research subjects were selected using purposive sampling, taking into account students' academic abilities based on previous assessment results, with the categories divided as shown in Table 1 below.

Table 1. Student Grade Categories

Grade	Category

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84–100	High
75–83	Moderate
< 75	Low

A total of nine students were selected as research subjects, consisting of three students in the high category, three in the moderate category, and three in the low category. The selection of subjects from these three categories aimed to provide a more diverse picture of student creativity during STEAM learning through an EDP-based pop-up book project. From the nine research subjects, one subject from each category was selected as the primary subject of analysis because they demonstrated complete and representative data regarding creativity in STEAM learning through the pop-up book project with EDP. This study focused its analysis on three indicators of creativity: originality, flexibility, and elaboration, as these three indicators are most relevant to the characteristics of the pop-up book project, which requires the ability to generate ideas, adapt designs, and develop products.

Research data were collected through observation, interviews, documentation, and product analysis. Observations were conducted to monitor student activities during STEAM learning and the pop-up book creation process. Semi-structured interviews were conducted to obtain in-depth information regarding students' ideas, thought processes, and experiences while working on the pop-up book project. Documentation was used to support the research data, and product analysis was conducted to assess the creativity demonstrated during the learning process. The primary instrument in this study was the researcher, while supporting instruments included observation sheets, interview guidelines, and documentation. Data were analyzed using the Miles and Huberman model, which consists of four main stages: data collection, data reduction, data presentation, and drawing conclusions and verification. Student creativity was analyzed based on three indicators: originality, flexibility, and elaboration.

RESULTS AND DISCUSSION

Implementation of EDP-Based STEAM in the Pop-up Book Project

This study was conducted with ninth-grade students at SMP Negeri 2 Girimarto during the 2025/2026 academic year. In the implementation, learning was designed based on STEAM, which allowed students to connect mathematical concepts with various other disciplines, making learning more contextual. The Science aspect was evident when students understood the principles of folding and movement in pop-up books. The Technology aspect was evident in the use of various simple tools such as scissors, rulers, cutters, and paper in the pop-up book creation process. The Engineering aspect was evident when students designed and tested the folds to ensure the pop-ups moved properly. The Art aspect was evident in the students' creativity in designing the visual appearance of the pop-up book, while the Mathematics aspect was evident in the application of mathematical concepts in the design and calculations used in the creation of the pop-up book. The learning process for creating this pop-up book project was carried out through several activities in accordance with the STEAM learning approach, using the EDP steps: Ask, Imagine, Plan, Create, and Improve (Hester & Cunningham, 2017).

Through the various activities carried out during the learning process, students developed their creativity in designing the appearance and mechanisms of their pop-up books. Thus, learning through the creation of a STEAM-based pop-up book project and hands-on activities provided students with an active, creative, and contextual learning experience. The implementation of STEAM-based learning in this study followed the Engineering Design Process (EDP). Each stage of the learning process provided students with the opportunity to be directly involved in planning and creating pop-up books. The implementation of learning in each stage of the EDP is described as follows.

Ask Stage

In the Ask stage, the teacher presents a contextual problem related to the surface area of cylinders and cones, then provides several examples of three-dimensional shapes and pop-up book models, and distributes the worksheets to be completed. In this activity, students examine and observe the three-dimensional shapes and pop-up books provided by the teacher as part of the initial hands-on activity, as shown in Figure 2 below.

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Figure 2. Students exploring the pop-up book model

Results from brief interviews with several students indicated that they were interested and enthusiastic about the project they would create. They also asked several questions regarding the project, such as what materials were needed, the content of the pop-up book, whether it would be completed individually or in groups, and when the pop-up books were due. During this Ask phase, students also identified issues related to creating the pop-up book, such as what materials are needed, the elements to be included in the pop-up book, and the mechanisms to be used. In groups, students also identified and discussed what others have done regarding pop-up book creation through online resources.

Image Stage (Imagine)

In the Image (Imagine) stage, students develop initial design ideas for the pop-up book through group discussions. Students discuss their group's theme, then create their own initial sketches based on the group's theme, add annotations to the sketches, and discuss folding mechanisms using simple paper. At this stage, students are expected to make a list of potential solutions, brainstorm ideas, and then select the best idea. Based on observations, the process of determining the pop-up book theme went smoothly. The decision was made through discussion; nearly every group member offered suggestions and ideas, but in most cases, the theme was agreed upon unanimously without significant disagreement. At this stage, students also continued to examine several pop-up book examples brought by the teacher, check the folding mechanisms, and explore ideas from the internet, YouTube, TikTok, Pinterest, and other media. Some groups were still discussing the number of pages in the pop-up book, its content, and the type of decorations, as shown in Figure 3 below.

Figure 3. Students drawing initial sketches

Plan Stage

Moving into the Plan stage, students develop a plan for creating the pop-up book based on what was outlined in the previous stage. Students work in groups to organize the planning for the pop-up book's creation. Students begin drawing cone and cylinder nets according to the planned dimensions. Students take direct measurements using rulers and record the necessary calculations. In this stage, students engage in measuring, writing, drawing, and

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calculating. This stage demonstrates the concrete application of mathematical and technological elements in product planning.

Figure 4. Students measuring and performing calculations

Create Stage

In the Create stage, students make pop-up books through activities that include cutting, folding, and assembling nets and parts of three-dimensional shapes. Observations made while students were working on this activity showed that students were actively involved in the process of making pop-up books, as shown in Figure 5. Based on observations during the creation of the pop-up book, particularly regarding the templates for cylinders and cones, many students created them without adhering to the initial plans they had devised. The construction of the cylinder and cone shapes as fillers for the pop-up book was also done without following the previously planned dimensions. The results of the net and pop-up structures, when the opening and closing mechanisms were implemented, were ultimately inaccurate: some were too large, some too small, some filled the entire pop-up book page, and some could not be opened or closed.

Figure 5. Pop-up book creation activity

For students and groups who took measurements according to the plan, many of the pop-ups and the cylinder and cone nets turned out correctly, and their opening and closing mechanisms worked smoothly. Nevertheless, the process of cutting out the nets and pop-up structures also affects the final result. For students who created the cylinder and cone nets by measuring and drawing them accurately, but then cut them out imprecisely, the pop-ups did not fit properly or interfered with the pop-up book mechanism on other pages.

For students who created nets as well as cylinder and cone shapes for pop-ups that were measured precisely according to the plan, drawn with a ruler and compass, and cut precisely along the drawn lines, their pop-ups functioned well. Regarding pop-up mechanisms, students explored the internet extensively as well as examples of pop-up books brought by the teacher. There are various mechanisms for folding, cutting, and gluing for the creation of pop-up books. Some students used different opening and closing techniques, while others got creative with

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mechanisms different from those used by most students in their class. Based on the observations, students demonstrated creativity in their pop-up mechanisms, including V-folds, parallel folds, pull-out mechanisms, and, most notably, boxes and cylinders featuring cylindrical and conical objects that emerge perpendicular to the page when the pop-up is opened.

Improve Stage

In the Improve stage, students evaluate the pop-up books they have created by directly testing the functionality of the pop-up mechanisms. In this stage, the finalization of the pop-up book design is also carried out by checking the content's suitability, the accuracy of the pop-up mechanisms, as well as the addition of decorations and necessary elements. During the Improve stage, discussions are also held regarding aspects that still need improvement to refine the pop-up book that has been created. Each group member provided feedback and suggestions for improvements to the pop-up book. Observations also revealed that students revised their pop-up book products, retested the improved mechanisms, and recalculated the dimensions of the three-dimensional shapes to achieve optimal results. This activity demonstrates a process of reflection through hands-on experience and reinforces engineering principles in the learning process.

Figure 6. Revising the *pop-up book*

Student Creativity in the Pop-up Book Project

Subject 1 (S1) High Category

In terms of originality, S1 demonstrated good originality. Based on observations, S1 appeared to propose a pop-up book design idea different from other group members; it was noted that S1's group chose the "Birthday Party" theme. According to S1's interview, the group's theme selection was determined through discussion among group members. The reason for choosing this theme, according to S1, was that the shapes of cylinders and cones in a Birthday Party setting are easily found in daily life. Throughout the process of creating the pop-up book until its completion, S1 integrated elements of art, technology, engineering, and mathematics into the pop-up book design. The chosen theme highlights the mathematical concepts of curved-surface three-dimensional shapes—cylinders and cones—in everyday life. The folding and pulling mechanisms used in the pop-up book design demonstrate the application of technology and engineering, ensuring the pop-up book is well-constructed. Artistic elements were also integrated during the creation of the pop-up book; S1 noted that the decorations applied to the pop-up book were relevant to the theme. These findings indicate that S1's originality is evident not only in the final product but also in the decision-making process during project design. S1's active engagement in proposing ideas and exploring various references enables the emergence of a wider range of ideas compared to students in other categories.

In terms of flexibility, S1 demonstrated good flexibility both in designing and creating the pop-up book. S1 adapted the design when materials were unavailable or time was limited. S1 did not stick to a single approach but was able to seek alternatives while remaining focused on the project's objectives. When the pop-up book encountered issues, S1 worked to refine the design after the initial version did not function properly. Based on the interview results and the LKPD results, there were several changes made to the pop-up book design. Design changes included adjusting the size of the cones, modifying the folding mechanisms, and correcting the tube grids that were improperly sized when pulled. The ability to revise the design demonstrates that S1 is not rigidly attached to the initial design. The ability to adjust strategies when facing obstacles is a form of flexible thinking.

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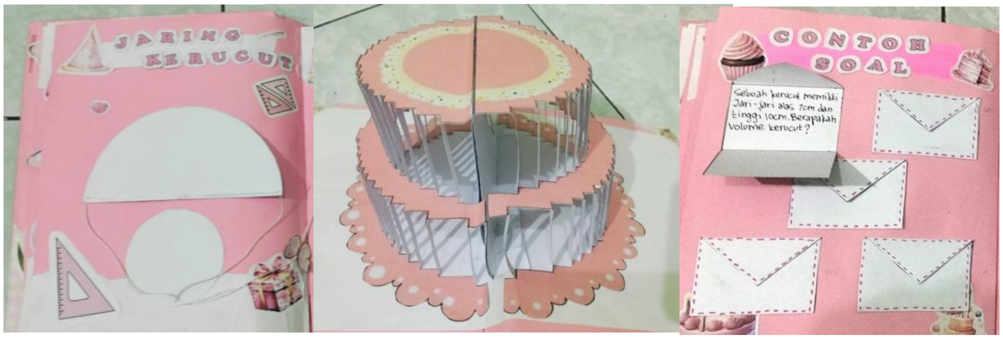

Figure 7. Subject 1's pop-up book

Based on Figure 2, S1's elaboration skills are notably prominent. Observations show that S1 not only created sketches and a basic design but also developed the pop-up book with complete details. S1 also added a unique element to the design—the inclusion of several practice questions at the end of the pop-up book—which is absent in other designs. The inclusion of practice questions indicates that S1 did not merely focus on completing the task but also enhanced the product to make it more informative and functional. This demonstrates a high level of elaboration, as the student was able to enrich the initial idea into a meaningful, complete product.

Overall, S1 demonstrates high creativity in the aspects of originality, flexibility, and elaboration. These abilities are evident in S1's active engagement in presenting ideas and concepts, making design adjustments when facing challenges, and developing the pop-up book in detail. S1's high level of creativity is likely influenced by their involvement in the EDP stages, particularly the image, create, and improve stages. In the image stage, S1 was able to explore various design possibilities and select appropriate solutions. In Create and Improve stages, S1 demonstrated the ability to evaluate and refine their work, resulting in a better pop-up book. These findings indicate that students' active engagement in the design process and reflection contributes to the development of their creativity.

Subject 2 (S2) Moderate Category

Based on observations regarding originality, S2 did not appear to propose pop-up book design ideas distinct from those of other group members. The pop-up book theme in S2's group was nearly identical to that of other groups—a "Birthday Party" theme. S2 also did not demonstrate novel approaches to completing project components. While working on the pop-up book, S2 utilized their own ideas, though they also sought inspiration through other media, such as TikTok. During the process of creating the pop-up book, S2 also looked at the work of other group members for inspiration. S2 appeared to integrate elements of art, technology, engineering, and mathematics into the pop-up book. Based on the observations, S2 integrated technology and engineering in the form of the opening and closing mechanism of the pop-up structures. The integration of art was demonstrated by the inclusion of decorations appropriate to the theme in the pop-up book, while the integration of mathematics was evident in the measurement process, the creation of the structures and the nets of cylinders and cones, as well as the inclusion of mathematical formula elements.

Based on observations regarding flexibility, it appears that S2 demonstrated good flexibility when designing and creating the pop-up book. S2 adjusted the design when materials were unavailable or time was limited. S2 stated that if time was limited, the work would be completed at home, and if materials were unavailable, S2 would purchase them. From these responses, it is evident that S2 has solutions for time and material constraints; however, these are merely short-term practical solutions and do not yet indicate better alternative solutions. When the pop-up book encountered issues, S2 appeared to attempt to improve the design after the initial result did not function properly. Based on the interview and observation results, S2 appeared to make improvements, although the process was repeated from the beginning.

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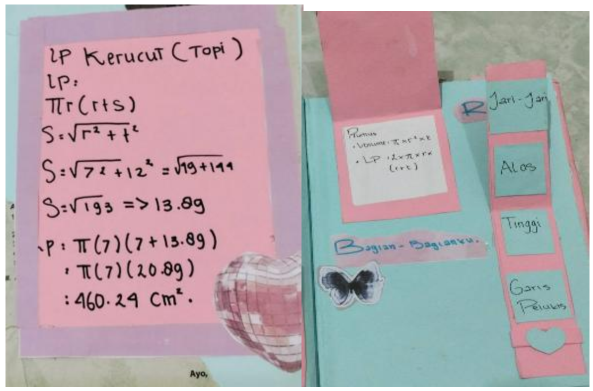

Figure 8. S2's pop-up book

Based on Figure 3, regarding the elaboration aspect, S2 added colors, decorations, or aesthetic elements that support the mathematical concepts in the pop-up book. S2's pop-up book also included the formula ` `, which aligns with the mathematical concept. Based on the interview results, it was noted that the pop-up book design also incorporated decorations and images to make it more appealing. Based on the results of observations and interviews, changes and design developments in S2's pop-up book are also evident. This is because during the pop-up book creation process, numerous adjustments were made regarding both size and pop-up mechanisms. The results of observations, interviews, and analysis of S4's pop-up book demonstrate an effort to integrate artistic, technological, and engineering elements with mathematical concepts. However, in the selection of theme ideas and pop-up book design, there is no evidence of new creative ideas or innovative approaches to completing the project. The pop-up book design created lacks uniqueness compared to those of other students.

Based on the results of observations, interviews, and product analysis, S2's creativity is rated as fairly good. S2 has demonstrated the ability to develop products and make improvements when encountering obstacles; however, the ideas used still largely draw from existing examples. This indicates that flexibility and elaboration skills are beginning to develop, although originality has not yet emerged optimally. During the EDP implementation, S2 appeared capable of following each stage well, but did not fully utilize the image stage to produce a pop-up book that was more unique and distinct from those of other students. This finding indicates that the student's creativity develops gradually and requires broader opportunities to explore ideas and concepts independently.

Subject 3 (S3) Low Category

Based on the observation of the originality aspect, S3 did not appear to propose any pop-up book design ideas. Since the pop-up book theme was discussed in a group, S3 appeared passive and followed the group's consensus. S3 also did not demonstrate new approaches to completing the project components. When working on the pop-up book section, S3 relied on ideas from online sources such as YouTube or sought inspiration independently. In terms of integrating elements of art, technology, engineering, and mathematics into the pop-up book, S3 was not observed to do so. S3 viewed the parts of the pop-up book as separate components that were not integrated. From the interview, it was learned that S3 had not yet realized that the pop-up book is a project whose creation process involves the integration of art, technology, engineering, and mathematical concepts into a single cohesive whole.

Based on the observations, regarding flexibility, S3 demonstrated good flexibility both in designing and creating the pop-up book. S3 appeared to adapt the design when materials were unavailable or time was limited; however, these solutions were merely short-term practical workarounds. When the pop-up book encountered issues, S3 did not attempt to revise the design after the initial version failed to function properly. Based on the observation results, regarding the elaboration aspect, S3 added colors, decorations, or aesthetic elements that supported the mathematical concepts in the pop-up book created. S3's pop-up book included three-dimensional shapes and decorations aligned with the theme. Based on the results of observations and interviews, it was found that the pop-up book design did not include text elements, labels, or explanations because S3 cited a lack of time to complete the

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work. Although S3 mentioned that when faced with time constraints, the work could be completed at home, the results of the interviews, observations, and the pop-up book itself showed no addition of text or explanations, as seen in Figure 9 below.

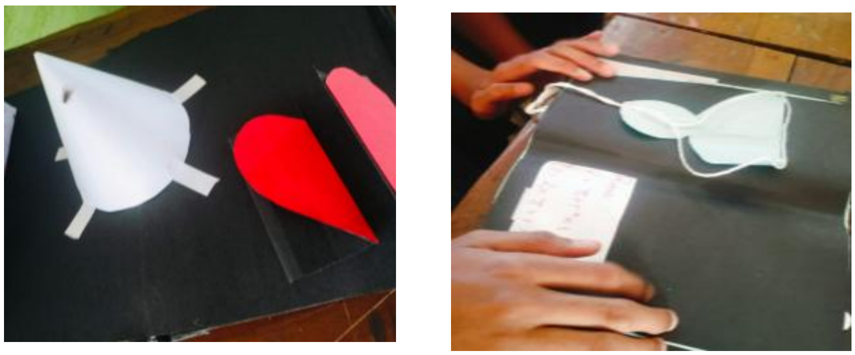

Figure 9. S3's pop-up book

The research findings indicate that S3's creativity remains relatively low compared to other participants. This limitation is evident in S3's lack of initiative in proposing ideas and the minimal development of the created pop-up book. Nevertheless, S3 still demonstrated efforts to complete the project and incorporated some visual elements aligned with the chosen theme. These findings indicate that student engagement in EDP-based STEAM projects does not automatically result in high creativity but is also influenced by students' prior abilities, motivation, and active participation during the learning process.

STEAM learning through an EDP-based pop-up book project fosters student engagement and gradually stimulates student creativity. This finding is supported by Pramasdyahsari *et al.* (2025), who found that integrating STEAM with geometry through hands-on and project-based activities enhances students' creativity, spatial understanding, and learning motivation. During the Ask and Imagine stages, students begin to identify problems related to pop-up book design. At this stage, high-performing students appear more active in developing ideas. Moderate and low-performing students only choose the easiest ideas or s only follow the group's instructions. During the Plan stage, students begin designing the pop-up book by considering artistic, technological, and engineering elements, with a primary focus on mathematical concepts. High-performing students were able to design systematically and integrate STEAM elements more clearly, while students in the moderate category demonstrated understanding but were not yet consistent. Students in the low-performing category still struggled to translate design concepts into structured planning.

During the Create stage, students engage in the hands-on process of making a pop-up book through a variety of activities that provide direct, concrete experiences. Findings indicate that during this process, students begin to develop their ability to evaluate arguments and demonstrate flexibility. In the Improve stage, students reflect on the results they have produced. High-performing students demonstrate strong reflective skills by conducting a thorough review and reflecting on the process from the initial planning phase through to the final inspection of the pop-up book. Students in the moderate category limited their reflection and improvements to functional and neatness aspects, while those in the low category tended to make minimal improvements without further development. Overall, STEAM-based pop-up book project learning through the EDP stages proved to provide a more meaningful learning experience through hands-on activities.

Based on the research findings, students' creativity in the learning process also showed significant differences among high, moderate, and low-performing students. In terms of originality, high-performing students were able to generate unique design ideas and integrate various elements into the design of their pop-up books. Students in the moderate category tended to follow existing examples, although they made efforts to adapt them to the group's needs. Students in the low category were unable to demonstrate specific ideas and tended to imitate or use simple designs. In terms of flexibility, high-category students were able to adjust their designs when facing obstacles. Moderate-category students showed the ability to make design adjustments, but these were limited to simple modifications.

Meanwhile, students in the low category face difficulties in adapting designs when changes occur. Regarding elaboration, high-category students can develop ideas into more complex products with diverse elements and components. Intermediate-category students have also added some supporting elements but have not developed them optimally. Low-category students, however, only add simple elements without providing detailed explanations.

Differences in creativity among S1, S2, and S3 indicate that the implementation of STEAM through EDP-based pop-up book projects provides the same learning experience to all students, yet the outcomes achieved vary according to each student's characteristics. S1 students effectively utilize each stage of the EDP process as a means to explore, develop, and refine ideas, resulting in more creative pop-up books. Grade 2 students showed fairly good creative development but still require support to generate more original ideas. Meanwhile, Grade 3 students tended to use the EDP stages merely to complete tasks without engaging in in-depth idea development. These findings indicate that the effectiveness of EDP-based STEAM learning in fostering creativity is influenced not only by instructional design but also by students' active engagement and prior knowledge during the learning process.

CONCLUSION

This study concludes that STEAM-based learning through EDP-based pop-up book project effectively facilitates the development of students' creativity in mathematics learning. The implementation of the Ask, Imagine, Plan, Create, and Improve stages provides meaningful learning experiences that enable students to integrate science, technology, engineering, art, and mathematics into tangible products. These findings indicate that project-based STEAM learning supports both conceptual understanding and the application of mathematical ideas in contextual situations. These findings are consistent with Rahim and Mahmud (2025), who highlight that the Engineering Design Process (EDP) support students in developing design thinking, problem-solving skills, and creativity through iterative and collaborative processes.

Student creativity as reflected in originality, flexibility, and elaboration, varies across performance levels. High-performing students demonstrate strong abilities in generating original ideas, flexibility in overcoming obstacles, and the development of detailed and complex products. Moderate-performing students show adequate creativity, but tend to rely on existing ideas and demonstrate limited development. Meanwhile, low-performing students exhibit minimal creativity, characterized by simple ideas, limited product development, and difficulty in adapting designs.

The findings also reveal that each stage of the EDP contributes differently to creativity development. These results imply that STEAM-based project learning can serve as an effective instructional strategy to enhance student's creativity However, its successful implementation requires active teacher guidance and adequate institutional support, including the provision of learning resources and teacher training, to ensure that students not only focus on product creation but also understand the underlying mathematical concepts.

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