



Development of a Geometric Transformation Pop-Up Book to Improve Students' Problem-Solving Skills

Laila Fitriana,* & Fathul Munawaroh

Department of Mathematics Education, Universitas Sebelas Maret, Indonesia

Abstract: Problem-solving skills are crucial in mathematics education as they are one of the mathematics learning objectives. However, based on PISA results, students' problem-solving skills in Indonesia are still low, necessitating efforts to address this issue. Based on this problem, this study aims to develop a valid, practical, and effective pop-up book learning media to improve problem-solving skills in geometry transformation materials. This developmental study used the ADDIE development model, which consisted of analysis, design, development, implementation, and evaluation. This research employed a quasi-experimental design using two classes with similar problem-solving abilities as the experimental and control classes, as demonstrated by an average balance test on pretest scores. Each class contains 31 students. Learning media is considered valid and practical if its validity and practicality scores are 61% or higher. Learning media is deemed effective if it can improve students' problem-solving skills, as evidenced by a t-test on the students' post-test scores. The research results show that the pop-up book learning media is very valid, with an average score of 81.25% from material experts and 83.33% from media experts. The pop-up book media is considered very practical based on the teacher's response score of 83.33% and students' response score of 84.11%. Additionally, the experimental class in this study showed a statistically significant improvement with a p-value of 0.004 (less than 0.05) compared to the control class; thus, the pop-up book learning media can be declared effective in improving students' problem-solving skills. Therefore, it can be concluded that the pop-up book learning media is very valid, practical, and effective in enhancing students' problem-solving abilities in geometric transformation.

Keywords: pop-up book, learning media, problem-solving skills.

▪ INTRODUCTION

Learning is defined as the acquisition of knowledge to change behavior (Schneider, 2024). One form of learning is through education. Law of the Republic of Indonesia number 20 of 2003 states that education is a conscious and planned effort to create a learning atmosphere and process so that learners actively develop their potential to possess religious spiritual strength, self-control, personality, intelligence, noble character, as well as the skills necessary for themselves, society, nation, and state. The place where the educational process takes place is called an academic institution. There are three academic institutions: formal, non-formal, and informal. Formal education, particularly primary and secondary education, must include mathematics. D'Ambrosio (2007) states that history reveals that the technological, industrial, military, economic, and political complexes have developed in part due to mathematics, thereby recognizing that mathematics is the most universal mode of thought and that survival depends on it. Mathematics, a universal language of logic and structure, plays a central role in shaping students' intellectual development. It trains learners to have abilities essential not only in academic contexts but also in everyday life.

As stated by the National Council of Teachers of Mathematics (NCTM), one of the goals of mathematics education is to develop problem-solving skills. Problem-solving

skills have an important place, not only in mathematics but also in real life (Özreçberoğlu & Çağanağa, 2018). Therefore, the low problem-solving skills of students continue to be a significant issue in Indonesian education. This is indicated by the Programme for International Student Assessment (PISA) scores, which remain below the global average. Problem-solving skills refer to a student's ability to solve mathematical problems systematically by linking their past experiences to the problems they are currently facing. In problem-solving, students learn several cognitive processes, such as understanding the problem, devising a plan, carrying out the plan, and reviewing the solution. This process is aligned with Polya's opinion (1973). Lack of mastery in these processes makes students rely on rote memorization rather than meaningful understanding.

The use of learning media is linked to students' problem-solving abilities, as the appropriate use of learning media can positively impact students' problem-solving skills, particularly in geometric transformation. This is reinforced by the research conducted by Shaghaghian et al. (2021) and Nguyen et al. (2023), which shows a positive effect of media use on students' problem-solving abilities in geometric transformation. Moreover, effective learning media can bridge the gap between concrete and abstract thinking, allowing students to manipulate figures. As a result, students are more engaged, motivated, and able to transfer their understanding to novel problems. To address this issue, mathematics instruction must emphasize conceptual understanding. This can be supported by using appropriate learning media that engage students in active learning. Providing learning experiences that encourage exploration and reasoning can help students improve their ability to solve problems in a more structured way.

According to the Cognitive Theory of Multimedia Learning (Mayer, 2009), students learn more effectively when presented with verbal and visual information. One key design guideline from this theory is the Multimedia Principle, which states that people learn better from words and relevant images than from words alone (Mayer, 2014). In the context of mathematics education, particularly in topics of geometric transformation, the use of instructional materials that are presented both verbally and visually becomes highly relevant, making abstract mathematical concepts in those materials easier to understand.

Media is a tool or object that serves as a connector between the message receiver and the message sender, which can be manipulated, seen, heard, and read, and can stimulate the thoughts, feelings, attention, and interests of the message receiver. Strate (2010) states that media is a message because content cannot exist without a medium. The media used in learning is referred to as learning media. Levie and Lentz (1982) state that learning media serve four main functions. First, the attention function is to attract and direct students' attention, allowing them to concentrate on learning. Second, the affective function stimulates students' emotions and interests. Third, the cognitive function assists students in faster understanding and remembering the learning material. The last is a compensatory function to support students struggling with verbal information.

One type of learning media that aligns well with the multimedia functions outlined by Levie and Lentz is the pop-up book. The pop-up book is a printed book that uses paper mechanisms such as folds, rolls, shapes, wheels, or spins, allowing for movable parts or the creation of three-dimensional objects. This learning medium combines both verbal and visual elements. In addition to the cognitive theory of multimedia learning, this learning media is also supported by the embodied cognitive theory, which emphasizes

that mental processes are fundamentally grounded in bodily interactions with the environment (Wilson, 2002). Learning involves both sensory and motor experiences. This theory aligns with Barsalou's (2008) opinion that states cognition is underlain by grounded cognition, proposing that modal simulations, bodily states, and situated action are involved. Therefore, students need to interact with the physical representation object. The physical interaction in a pop-up book happens when students open, rotate, or manipulate the components. This interaction creates a unique experience for them, making learning using pop-up books more interactive and enjoyable.

In addition, using pop-up books as a learning medium has also been proven effective in improving students' learning outcomes and mathematical communication skills (Komari et al., 2022; Andreansyah & Sari, 2024; Fazira & Qohar, Kariadinata, 2024; Sawitri, Wiarta, & Wulandari, 2024). Nevertheless, these studies do not specifically investigate the relationship between pop-up book learning media and problem-solving skills in geometric transformations. O'Rourke (2022) highlights the mathematical mechanisms underlying pop-up constructions, emphasizing the rich potential of pop-ups for teaching geometric concepts. Therefore, further research is needed to examine how pop-up book media can support students in solving geometric transformation problems, which remain challenging in mathematics learning. Geometric transformation is one of the mathematical concepts that has proven difficult for students and affects their low problem-solving abilities. This material is challenging for students due to its abstract nature and the need for good spatial visualization skills. Many students still struggle to understand the concept of geometric transformation, which impacts their ability to solve problems related to the topic (Fan et al., 2017; Mardiana & Amalia, 2023; Tursynkulova et al., 2023; Xie et al., 2025). Therefore, this research aims to develop pop-up book learning media to improve problem-solving skills in geometric transformation.

▪ **METHOD**

Participants

The subjects of this research comprise 31 ninth-grade students in an experimental class and 31 ninth-grade students in a control class, totaling 62 ninth-grade students, to test the effectiveness of pop-up book learning media. The sampling technique used was purposive sampling, which involved two classes based on the similarity of their pretest mean scores. This research also involves four expert validators, comprising two subject matter experts and two media experts, to assess the validity of the learning media. Furthermore, the practicality of the learning media is evaluated by the mathematics teacher and students in the experimental class.

Research Design and Procedures

The type of research used is research and development (R&D), which involves producing products and testing their effectiveness (Sugiyono, 2013). This research employed a quasi-experimental approach using a non-equivalent control group pretest-posttest design. In this design, two groups have similar characteristics: one group receives the treatment as the experimental class and another serves as the control class (Capili & Anastasi, 2024). The experimental class in this research conducted learning activities using pop-up book learning media. Meanwhile, the control class in this research used the media that teachers usually use, namely PowerPoint. This research procedure uses

ADDIE. The ADDIE model has five stages: analysis, design, development, implementation, and evaluation (Branch, 2009).

Instruments

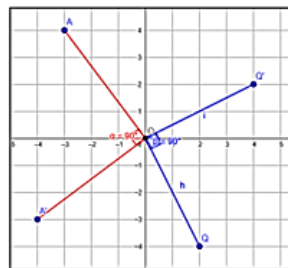
This research used validation sheets for the validation test, teacher response questionnaires, and students' response questionnaires to assess validity, as well as problem-solving skills test instruments for the effectiveness test of the learning media, consisting of a pretest and a posttest. There are four essay questions for each of the pretest and posttest, with question number 1 related to the submaterial of translation, question number 2 about the submaterial of reflection, question number 3 about the submaterial of rotation, and question number 4 associated with the submaterial of dilation. According to Polya, problem-solving consists of four key indicators: understanding the problem, devising a plan, carrying out the plan, and reflecting on the outcome (Kho et al., 2024). To clarify how each indicator is reflected in the assessment, the following is an example of an essay question that incorporates Polya's problem-solving steps.

3. Titik $A(-3,4)$ dirotasikan dengan sudut α dengan pusat rotasi $O(0,0)$ menghasilkan bayangan $A'(-4, -3)$. Tentukan bayangan titik $B(2,5)$ jika dirotasikan terhadap pusat $O(0,0)$ dengan sudut yang sama yaitu α !
- Dari informasi di atas, tuliskan hal-hal yang diketahui dan ditanyakan!
 - Tuliskan langkah-langkah, rumus, atau rencana yang akan kamu kerjakan untuk menyelesaikan masalah tersebut!
 - Selesaikan langkah penyelesaian masalah sesuai dengan rencana yang telah dibuat!
 - Buat garis melalui titik $A(-3,4)$ dan titik $O(0,0)$ serta garis melalui titik $O(0,0)$ dan $A'(-4, -3)$. Berapa besar sudut yang terbentuk dari dua garis tersebut? Kemudian tentukan letak titik bayangan $B(2,5)$ pada bidang koordinat kartesius jika dirotasikan terhadap pusat $O(0,0)$ dengan sudut yang sama!

Figure 1. Essay question

The question in image 1 contains indicators of the steps to solve problems, with point a containing the indicator of understanding the problem, point b containing the indicator of devising a plan, point c containing the indicator of carrying out the plan, and point d containing the indicator of looking back. The following model answer illustrates how each step of Polya's problem-solving process is ideally applied to this question.

3. a. Diketahui:
Titik $A(-3,4)$, pusat rotasi $O(0,0)$, bayangannya $A'(-4, -3)$
Ditanya:
Tentukan bayangan titik $B(2,5)$ jika dirotasikan terhadap pusat $O(0,0)$ dengan sudut yang sama yaitu α !
- b. Menemukan sudut α dengan mengetahui rumus refleksi yang sesuai dengan yang terjadi pada titik A.
- $$A(-3,4) \xrightarrow{R[0,\alpha]} A'(-4, -3)$$
- Setelah mengetahui rumus yang digunakan kemudian rumus tersebut diterapkan pada titik berikut.
- $$B(2,5) \xrightarrow{R[0,\alpha]} B'(x', y')$$
- c. Pada soal diketahui $A(-3,4) \xrightarrow{R[0,\alpha]} A'(-4, -3)$
- Maka rumus yang sesuai yaitu $P(x, y) \xrightarrow{R[0,\alpha]} P'(-y, x)$
Ini merupakan rumus dari rotasi terhadap $O(0,0)$ dengan sudut rotasi 90° sehingga diperoleh $\alpha = 90^\circ$
- $$Q(2, -4) \xrightarrow{R[0,90^\circ]} Q'(4, 2)$$



Sudut yang terbentuk yaitu 90° .

Jadi sudut $\alpha = 90^\circ$ dan bayangan yang hasil rotasi dari titik $Q(2, -4)$ adalah $Q'(4, 2)$

Figure 2. Model answer

While the model answer demonstrates an ideal and structured approach based on Polya's indicators, it is important to note that students may employ alternative strategies or solution paths to arrive at the correct answer. These variations are acceptable as long as the essential elements of problem-solving, including understanding the problem, planning, executing the plan, and reviewing the solution, are evident in their responses. Allowing flexibility in problem-solving approaches encourages students' creativity and critical thinking, supporting a more comprehensive assessment of their mathematical reasoning.

Data Analysis

Data analysis techniques were employed in this research to evaluate the validity, practicality, and effectiveness of pop-up book learning media. The questionnaire assessment data used scoring items on a four-point Likert scale, ranging from "strongly agree" (score of 4) to "strongly disagree" (score of 1). The questionnaire was based on rules for validity and practicality. The score obtained was calculated using the average percentage formula. The interpretation criteria for percentage scores were based on Riduwan (2015), who classifies them into five levels. A score ranging from 81% to 100% is categorized as very high, indicating excellent results. Scores within 61% to 80% are considered high. The sufficient category includes scores from 41% to 60%. Scores between 21% and 40% fall under the low category, showing that significant improvements are required. Lastly, scores ranging from 0% to 20% are very low, indicating poor performance that necessitates serious attention. The developed product is considered valid and practical if it achieves a score of 61% or higher.

The effectiveness of learning media in improving students' problem-solving skills was evaluated using an independent samples t-test with Microsoft Excel. The pretest data is for the balance test, and the posttest data is for the hypothesis test. Learning media are considered effective if they can improve students' problem-solving skills.

RESULT AND DISCUSSION

Based on the description, researchers wanted to develop pop-up book learning media using the ADDIE model, which is described as follows.

Analysis

Problem-solving skills are essential in mathematics, as they are one of the key learning objectives in the subject. However, data from the field indicate that the problem-

solving skills of students in Indonesia remain low. Therefore, solutions are needed to address this issue. Based on the results of interviews with teachers, mathematics learning uses PowerPoint media. However, this learning media cannot optimally attract students' attention to focus on the learning process. Additionally, the school rule prohibiting junior high school students from bringing smartphones into the school environment is also a consideration in determining the steps to be taken as an effort to address the existing problems. As a solution to this condition, the pop-up book learning media was chosen because it does not require electronic devices while still providing an engaging visual and interactive learning experience. The pop-up book provides students with a concrete representation of abstract mathematical concepts, thereby enhancing their problem-solving skills.

Design

The developed product measures A3 when opened and A4 when closed. The pop-up book media employs v-folding, box, flap, and rotary techniques in its creation. The product content is printed on art carton paper with a thickness of 260 gsm. The cover is made of cardboard coated with 150 gsm art paper. This product contains 24 pages. Each section consists of concrete examples of the material, examples in Cartesian coordinate fields, formulas, and their explanations. There are pop-up chess games as a concrete example of translation, mirror illustrations as an example of reflection, windmills as an example of rotation, and image scaling as an example of dilation. The pop-up book features illustrations designed using Canva. The developed product is intended for use by teachers as a learning medium and for students, assisting them in independent or group learning. The researcher continues the design of learning media until producing a tangible product. The creation of learning media starts with printing the design, cutting out the pop-up elements, and then assembling them into a pop-up book.

Development

The developed media was then validated by media experts and material experts, and comments and suggestions were received. After that, the researcher revises the learning media according to the comments and suggestions from the experts until the media is declared valid. In this research, the validity of the questionnaire for subject matter experts is assessed in three aspects: content, language, and appearance. The validity results, as determined by subject matter experts, show that the media developed received a positive evaluation in all aspects, with the content aspect scoring 77.5%, which falls into the high category. The language aspect was rated 87.5%, categorized as very high, indicating clarity and appropriateness in language use. Meanwhile, the appearance aspect scored 81.25%, which was also categorized as very high, reflecting an attractive and user-friendly visual presentation. Overall, the final score from subject matter experts was 83.75%, which is interpreted as very high.

In addition, the evaluation by the media expert also showed that the media developed received a positive evaluation in all aspects. The physical element received a score of 83.33% and the design aspect was rated even higher at 84.75%, both of which fall into the very high category. The learning process aspect scored 79.17%, which falls into the high category. The final score from media experts was 83.33%, which is also very high. The results of the expert validation, received from both subject matter experts

and media experts, scored more than 61%. Therefore, the media developed is valid. The final result of the learning media tested on 31 students consists of 24 pages, including a cover, as shown in Figure 3. One of the content pages is illustrated in Figure 4.

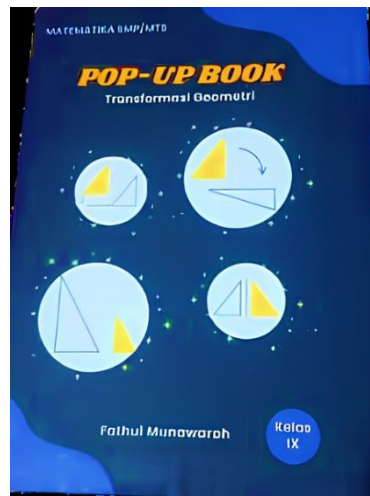


Figure 3. Display of a pop-up book cover



Figure 4. Display of pop-up book content

Implementation

After developing the media, this media was implemented in a junior high school with 31 students. The implementation in the class started with a pretest on problem-solving skills and learning using media, followed by a posttest on problem-solving skills, and concluded with a questionnaire for student responses.

Evaluation

At this stage, several shortcomings and limitations related to the researcher's abilities were identified in the developed learning media. The pop-up book learning media was made using 260 gsm art carton paper, making the production cost less affordable. Therefore, other researchers can use different types of paper that are more affordable but still strong enough to be used as pop-up media materials. The discussion of the dilation topic was still in a two-dimensional form because the researcher had not found a suitable pop-up mechanism for the material; therefore, other researchers can seek a pop-up mechanism that suits the dilation topic.

The analysis of the practicality data for the pop-up book is based on the results of the teacher's and students' response questionnaire assessments. Four aspects were assessed by teachers as practical data results, and students responded to three aspects. Based on the results of teacher responses, the ease of use aspect received a score of 90%, which falls into the very high category. The efficiency was rated 75%, categorized as high. The ease of storage and maintenance, as well as the learning process, obtained a score of 83.33%, which falls into the very high category. The final score of teacher responses was 83.33%, which is categorized as very high.

In addition, the students' responses show that the ease of use aspect received a score of 86.09% and the appearance aspect was rated even lower at 84.68%, both of which fall into the very high category. The time efficiency aspect obtained a score of 79.03%, which falls into the high category. Overall, the final score of students' responses was 84.11%, which is interpreted as very high.

. Users of learning media, both math teachers and students, gave the highest scores to the ease of use aspect because the learning media is easy to use, has a structured display, and simple language that is easy to understand, thereby attracting users' attention and being relevant to their needs. Additionally, the structured display and easy-to-understand language increase students' confidence, as they feel capable of understanding the material, resulting in greater satisfaction with the learning process. This indicates that the ease of use aspect received the highest score because the usability of the media not only facilitates access to the material but also supports the achievement of principles in the ARCS Model, which consists of Attention, Relevance, Confidence, and Satisfaction (Simol et al., 2023). The data analysis of the module's effectiveness was carried out using a t-test. Before that, the data must be tested for normality and homogeneity of variance.

Table 1. Normality test

Score Type	Class	<i>L</i>	<i>L_{Table}</i>
Pretest	Experiment	0.14	0.16
	Control	0.12	0.16
Posttest	Experiment	0.09	0.16
	Control	0.11	0.16

In Table 1, data from the pre-test of the experiment class and the control class have $L < L_{Table}$. So that the assumption of normality in the pre-test data is fulfilled. Additionally, data from the post-test of the experimental class and the control class also show $L < L_{Table}$. So that the assumption of data post-test normality is fulfilled.

Table 2. Homogeneity test

Score Type	<i>F</i>	<i>F_{Table}</i>
<i>Pre-test</i>	1.01	1.84
<i>Post-test</i>	<i>Post-test</i>	1.78

From Table 2, the obtained data from the pre-test is $F < F_{Table}$. So that the assumption of homogeneity is fulfilled, as well as the data obtained from the post-test. $F < F_{Table}$. So, the assumption of homogeneity is also fulfilled. Since the data were declared

normal and homogeneous, a t-test was subsequently conducted. The pre-test data is used to average the balance test.

Table 3. Average balance test

Class	N	Mean	Std. Deviation	df	t-value	p-value	Conclusion
Experimental	31	20.10	9.13	60	0.49	0.63	Not significant
Control	31	18.97	9.08				

Based on Table 3, the mean scores of the experimental and control groups do not differ significantly. The calculated t-value was 0.49 with a corresponding p-value of 0.63. The null hypothesis cannot be rejected because the p-value exceeds the conventional significance threshold of 0.05 ($p > 0.05$). This indicates that both groups had comparable initial abilities before the treatment was applied. The most significant improvement occurred at the third step of problem solving, according to Polya, which is carrying out the plan.

To determine the effectiveness of the pop-up book learning media in improving students' problem-solving skills, a t-test was conducted on the post-test results of the experimental class and the control class.

Table 4. T-test

Group	N	Mean	Std. Deviation	df	t-value	p-value	Conclusion
Experimental	31	66.16	15.99	60	2.77	0.004	Significant
Control	31	52.90	21.34				

Based on Table 4, the posttest mean score of the experimental group is significantly higher than the posttest mean score of the control group. The calculated t-value is 2.77 with a corresponding p-value of 0.004. This means that the null hypothesis is rejected because the p-value is less than the significance threshold of 0.05 ($p < 0.05$). This indicates that the pop-up book learning media successfully improve students' problem-solving abilities because its three-dimensional structure allows students to engage visually and physically with the learning material. Through touching, folding, and manipulating the pop-up elements, students experience a form of sensorimotor interaction that reinforces their understanding of abstract spatial concepts. This finding aligns with the principles of embodied cognition theory, which emphasizes that cognitive processes are fundamentally grounded in bodily interactions with the environment (Wilson, 2002).

Based on Table 4, the pop-up book learning media have been proven effective in improving students' problem-solving skills. Furthermore, a calculation will be conducted using n-gain to determine which indicators of overall problem-solving skills have shown significant improvement after using this media. As mentioned earlier, in this study, there are four indicators of problem-solving skills, namely understanding the problem, devising a plan, carrying out the plan, and looking back. Based on Figure 5, the indicator understanding the problem received an n-gain score of 0.57, categorized as a moderate increase. The indicator devising a plan achieved the highest n-gain score of 0.86, which falls into the high category. This indicates that learning through pop-up book media helps students design effective problem-solving strategies by providing hands-on interaction with visual elements, thereby better understanding and applying abstract concepts. This

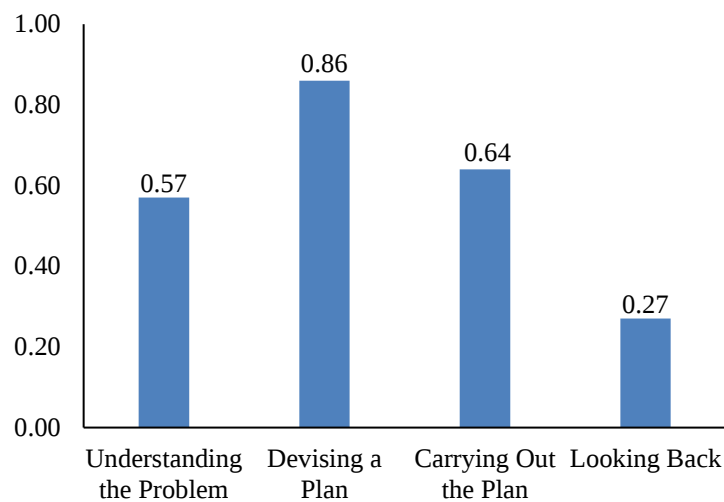


Figure 5. N-Gain score of each indicator.

finding aligns with research by Nguyen et al. (2023) and Shaghaghian et al. (2021), both of which reveal the benefits of interactive media in geometric transformation. The research by Nguyen et al. focuses on Geogebra-assisted problem-solving, whereas Shaghaghian et al. (2021) demonstrate that an augmented reality-powered approach can enhance students' understanding of geometric transformations. Both emphasize the importance of concrete three-dimensional learning experiences in improving students' problem-solving skills. Meanwhile, the indicator implementing the plan achieved an n-gain score of 0.64, categorized as moderate, indicating an improvement in students' ability to accurately implement problem-solving steps. However, the indicator, looking back, received an n-gain score of 0.27, which falls into the low category. This shows that students' ability to double-check the solutions obtained still needs improvement. Overall, the pop-up book media is particularly effective in supporting students in planning and implementing the steps of problem-solving. However, to further develop students' reflective skills, future implementations should consider incorporating additional tools or strategies to improve performance in the final phase of problem-solving.

▪ CONCLUSION

Based on the research results, it is concluded that pop-up book learning media, based on the multimedia principle, are proven to be highly valid, practical, and effective in improving students' problem-solving abilities in geometric transformations. This research finding also indicates that the effectiveness of the media is not only due to its visual design, but is strengthened by student engagement when using the media, such as activities involving sliding, rotating, and manipulating parts of the pop-up book, in relation to the Embodied Cognition Theory. Thus, the main contribution of this research is to provide empirical evidence that the development of valid, practical pop-up book learning media can enhance students' problem-solving abilities and serve as an innovative alternative in mathematics education.

This research identified several limitations that warrant further investigation. The results of the n-gain analysis show an improvement in all four problem-solving indicators, with the indicator of devising a plan receiving the largest increase in the high category.

In contrast, the indicators of carrying out the plan and understanding the problem showed moderate improvements. However, the indicator of looking back had a low increase, indicating that students still struggle with reflecting on and evaluating their problem-solving processes. This suggests that the pop-up book learning media is more effective in supporting the planning and implementation phases than in encouraging reflective thinking. To address this, future implementations should consider integrating reflection prompts to improve students' self-evaluation skills.

Additionally, technical limitations were identified in the media's production. The use of 260 gsm art carton paper makes the media less affordable, suggesting the need for cost-effective alternatives. Furthermore, the dilatation material in this medium remains in a two-dimensional format due to the lack of a suitable pop-up mechanism. Thus, future research is needed to explore or design innovative folding or engineering techniques better to represent dilatation in a three-dimensional and interactive format.

▪ ACKNOWLEDGMENT

The authors gratefully acknowledge the financial support provided by the Institute for Research and Community Service (LPPM) Universitas Sebelas Maret Surakarta, under grant number 371/UN27.22/PT.01.03/2025.

▪ REFERENCES

- Andreansyah, R., & Sari, E. Y. (2024). Development of a pop-up book-based mathematics learning media on three-dimensional shapes material for elementary school students. *Edunesia: Jurnal Ilmiah Pendidikan*, 5(3), 1671-1689.
- Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology*, 59, 617-645.
- Branch, R. M. (2009). *Instructional design: The ADDIE approach*. New York: Springer.
- Capili, B., & Anastasi, J. (2024). An introduction to types of quasi-experimental designs. *American Journal of Nursing*, 124(11), 50-52.
- D'Ambrosio, U. (2007). The role of mathematics in education systems., 39(1), 173-181.
- Fan, L., Qi, C., Liu, X., Wang, Y., & Lin, M. (2017). Does a transformation approach improve students' ability in constructing auxiliary lines for solving geometric problems? An intervention-based study with two Chinese classrooms. *Educational Studies in Mathematics*, 96(2), 229-248.
- Fazira, S. K., & Qohar, A. (2021, July). Development of pop-up book mathematics learning media on polyhedron topics. In *Journal of Physics: Conference Series* (Vol. 1957, No. 1, p. 012005). IOP Publishing.
- Kariadinata, R., Ajahra, E. S., & Jihad, A. (2024). Development of pop-up book media based on an investigative approach to improve the mathematical communication skills of junior high school students. *Jurnal Analisa*, 10(1), 26-42.
- Kho, R., Praja, N. I., & Tandililing, P. (2024). Using Polya steps to solve fraction story problems (case study in class VII SMP). *Journal on Education*, 6(4), 22527-22538.
- Komari, M., Widiyaningrum, P., & Partaya, P. (2022). Development of a pop-up book to increase interest and learning outcomes. *Journal of Innovative Science Education*, 11(1), 22-29.
- Lestari, K. E., & Yudhanegara, M. R. (2017). *Penelitian Pendidikan Matematika [Research in mathematics education]*. Bandung: PT Refika Aditama.

- Levie, W., & Lentz, R. (1982). Effects of text illustrations: A review of research. *Educational Communication and Technology Journal*, 30(4), 195–232.
- Mardiana & Amalia, Y. (2023). Analisis kesulitan siswa dalam memahami konsep geometri transformasi pada kelas VII di SMP Negeri 2 Kuala Kabupaten Nagan Raya [Analysis of students' difficulties in understanding the concept of transformation geometry in grade VII at SMP Negeri 2 Kuala, Nagan Raya District]. *Maju*, 10(1), 30-35.
- Mayer, R. E. (2009). *Multimedia learning (2nd ed.)*. Cambridge University Press.
- Mayer, R. E. (2014). Cognitive theory of multimedia learning. In R. E. Mayer, *The Cambridge Handbook of Multimedia Learning*. Cambridge: Cambridge University.
- Nguyen, H. V., Chu, T. M., Cuong, T. Q., Ha, V. T., Hoang, P. V., Phuong, T. D., & Thuy, T. L. (2023). Geogebra-assisted teaching of rotation in geometric problem solving. *International Conference on Mathematics, Modeling, Computational Science (ICMMCS)* (pp. 451-460). Springer.
- O'Rourke, J. (2022). *Pop-up geometry: The mathematics behind pop-up cards*. Cambridge University Press.
- Özreçberoğlu, N., & Çağanağa, Ç. K. (2018). Making it count: Strategies for improving problem-solving skills in mathematics for students and teachers' classroom Management. *Eurasia Journal of Mathematics, Science and Technology Education*, 14(4), 1253-1261.
- Riduwan. (2015). *Skala pengukuran variabel-variabel penelitian [Scales for measuring research variables]*. Bandung: Alfabeta.
- Sawitri, N. W., Wiarta, I. W., & Wulandari, I. G. A. A. (2024). Pop-Up book based on ethnomathematics effectively improves mathematical knowledge competence . *International Journal of Language and Literature*, 8(4), 201-210.
- Schneider, K. (2024). What is learning? *Psychology*, 15(5), 779–799.
- Shaghaghian, Z., Burte, H., & Yan, W. (2021). Learning geometric transformations for parametric design: an augmented reality (AR)-powered approach. *International conference on computer-aided architectural design futures*. Singapore: Springer.
- Simol, C. F., Yasin, M. H., & Mansor, A. B. (2023). Using the ARCS model to develop motivational web-based English instructional materials for learning disabilities students in Sabah. *International Journal of Academic Research in Progressive Education and Development*, 12(3), 171–185.
- Strate, L. (2010). Studying media as media. *Transforming McLuhan: Cultural, Critical, and Postmodern Perspectives*, 67.
- Sugiyono. (2013). *Metode penelitian kuantitatif, kualitatif, dan R&D [Quantitative, qualitative, and R&D research methods]*. Bandung: Alfabeta.
- Tursynkulova, E., Madiyarov, N., Sultanbek, T., & Duysebayeva, P. (2023, December). The Effect of Problem-Based Learning on Cognitive Skills in Solving Geometric Construction Problems: A Case Study in Kazakhstan. In *Frontiers in Education* (Vol. 8, p. 1284305). Frontiers Media SA.
- Wilson, M. (2002). Six views of embodied condition. *Psychonomic Bulletin & Review*, 9(4), 625–636.
- Xie, Z., Deng, Y., Zhang, Z., & Liu, J. (2025). Opportunities to learn geometric transformation in chinese mathematics textbook: a primary school example *International Journal of Science and Mathematics Education*, 1-29.