International Journal of Research and Review
[Indexed, Peer-Reviewed Journal]
Volume 13; Issue: 4; April 2026
Website: www.ijrrjournal.com
Research Paper *E-ISSN: 2349-9788; P-ISSN: 2454-2237*

Development of a Pop-Up Book Based on Problem-Based Learning to Improve Students' Learning Motivation and Critical Thinking Abilities

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DOI: https://doi.org/10.52403/ijrr.20260466

ABSTRACT

The purpose of this study is to develop media in the form of pop-up books based on problem-based learning (PBL) with certain characteristics and to analyze their validity, practicality, and effectiveness on the learning motivation and critical thinking skills of participants. This study uses the Research and Development (R&D) method with the development of the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). The trial subjects were 60 students of class VIII of Madrasah Tsanawiyah (MTs) Al Fithrah Meteseh Semarang who were divided into experimental and control classes. Data analysis includes validity using the Content Validity Index (CVI); practicality based on teacher and student responses; and the effectiveness of pop-up books on learning motivation and critical thinking skills using the t-test. The results of the study showed that the validity of the pop-up book based on expert assessment was in the very valid category; the practicality of the pop-up book based on teacher and student responses was in the very good category with an average score above 90%; the effectiveness of the pop-up book on learning motivation was shown by a significant increase in ARCS questionnaire scores in the experimental class compared to the control; and the effectiveness of the pop-up book on critical thinking skills ended with an increase in pretest-posttest test results, where most of the participating students achieved scores above the KKM with a high category score. It can be concluded that PBL-based pop-up books are effective in increasing students' learning motivation and critical thinking skills on the circulatory system material and are suitable for use as innovative learning media according to the demands of the Merdeka Curriculum.

Keywords: Pop Up Book, Problem Based Learning, Learning Motivation, Critical Thinking Skills

INTRODUCTION

The development of science in the 21st century has posed a major challenge in education. 21st-century learning focuses on developing the skills and competencies necessary to face the challenges of an increasingly complex and dynamic world, making it crucial for students to master 21st-century learning. The 21st-Century Learning framework explains that learning provides students with the 4Cs: communication, collaboration, critical

thinking, and creativity (Prayogi and Estetik, 2019:144). These four competencies form a crucial foundation for students to adapt to dynamic technological, social, and cultural developments. However, this study specifically highlights two essential competencies most relevant to science learning objectives: critical thinking and learning motivation. Critical thinking was chosen because it is a core skill for analyzing and solving real-world problems, while learning motivation is a determining factor in student active engagement in the learning process.

Research shows that the learning process often overlooks the objectives that should be achieved. A study by Sari and Prasetyo (2022) revealed that most teachers emphasize solely cognitive achievement while under-developing critical and creative thinking skills. This situation tends to make students passive and focused solely on memorization. This fact is further reinforced by findings in several secondary schools, which show that despite students' high academic scores, their ability to analyze real-world problems and make decisions remains low. This demonstrates that an imbalance in learning between cognitive aspects and 21st-century skills can hinder the achievement of true educational goals.

Critical thinking skills require the ability to analyze, evaluate, and make sound decisions. Critical thinking is an individual's ability to manage and solve problems and then evaluate them based on their own perspective (Masmuji, 2021). According to research by Rahmawati and Santosa (2022), teaching students to think critically is one of the primary goals of education. Students who can solve problems using their own expertise can positively influence the quality of their thinking in learning (Putri and Nugroho, 2021). In other words, critical thinking is not merely an additional skill but rather the core of the learning process, oriented toward developing life skills in modern society.

Students' critical thinking skills can be developed through learning that provides opportunities to enhance analytical thinking skills in solving complex problems encountered in everyday life through problem-based learning (PBL). PBL learning utilizes the intelligence of individuals, groups, and the environment to solve problems in a relevant and contextual manner (Octavianis, 2019). Thus, PBL not only functions as a learning method but also as a means to form students who are independent, creative, and able to face real challenges outside the classroom.

Critical thinking is a strategy used to manage information with various considerations in solving problems in the learning process. In addition to strategies and appropriate methods for addressing learning process problems, the use of suitable learning media also significantly influences the delivery of information to students. Learning media is considered a means of conveying material messages from teachers to students so that the material presented is well received. Appropriately used media can overcome passive students, encourage them to think innovatively, and make learning more effective (Tafono, 2018). Learning media is not merely a means of delivering information but can also encourage students to have a strong curiosity about the content presented by the teacher (Ahmad, 2020). Abstract material will be easier for students to understand when using appropriate learning media because interesting visualizations can bridge the gap between theoretical concepts and real-life experiences.

Observations conducted in schools indicate that the use of learning media is recognized as crucial, as it influences the effectiveness of material delivery. However, the media used by schools still relies on printed textbooks and worksheets (LKS). A questionnaire survey of 60 students revealed that 72% had difficulty analyzing the main problem, 65% were unable to make decisions, and 70% tended to simply memorize the material. This situation indicates that students' critical thinking skills are still low. According to

Purnaningsih (2022), the contributing factors include difficulty understanding the problem; lack of student interest and curiosity; and poor communication skills; passive, teacher-centered learning; and a lack of teacher pedagogical competence. Furthermore, student learning motivation is also low because learning methods emphasize lectures and minimal use of innovative media.

Motivation is a conscious effort made to provide encouragement to achieve a specific goal. This aligns with Uno's (2014) opinion, which states that motivation is a drive related to emotions, behavior, and knowledge that drives a person to achieve something. Thus, students' learning motivation can be enhanced through the use of media that is engaging, interactive, and tailored to their needs.

Based on previous research, PBL-based pop-up books have been shown to improve critical thinking skills and student learning motivation (Norra et al., 2019; Lestari, 2020). Furthermore, pop-up books display engaging three-dimensional elements and provide concrete visual experiences (Fitriani et al., 2020; Anggraini and Febrianto, 2022). The advantages of using pop-up books include improved critical thinking skills through more systematic problem analysis and increased learning motivation through engaging, interactive, and contextual visualizations. In other words, pop-up books function not only as a learning medium but also as a means to foster active student engagement in the learning process.

The relationship between PBL and pop-up books lies in their shared goals: to train students to think critically through solving real-world problems while simultaneously increasing learning motivation through engaging visualizations. Pop-up books support PBL by providing concrete media that facilitate students' understanding of problems, analysis, and solution discovery. Thus, they serve as a bridge between theory and practice, strengthening the effectiveness of the PBL method.

The circulatory system is a complex topic related to everyday life, making it ideal for application using the PBL method. Pop-up books present organs, blood circulation, and physiological processes in a concrete way, facilitating student understanding. The three-dimensional visualizations offered by pop-up books can help students see the relationships between organs, systematically understand blood circulation, and relate abstract concepts to real-life experiences. With this medium, students not only read or memorize text but also directly observe visual representations that resemble real-life situations. This makes learning more engaging, interactive, and meaningful. Furthermore, PBL-based pop-up books provide students with opportunities to discuss, analyze, and solve problems related to the circulatory system, thereby simultaneously developing critical thinking skills and learning motivation.

Research by Cahyani and Ahmad (2025) shows that PBL has a significant impact on improving student learning outcomes and motivation, while Uyun et al. (2025) confirm the consistency of PBL in developing critical thinking skills. A systematic review by Ngandung and Kuswandi (2025) also confirmed that PBL consistently improves learning motivation and critical thinking skills across various learning contexts. Therefore, the combination of pop-up books and PBL is believed to produce valid, effective learning media that aligns with the demands of the Independent Curriculum. This aligns with the Science Learning Outcomes in the Independent Curriculum, which requires students to understand the structure and function of human organ systems and their relationship to health. Therefore, the complex and contextual material on the circulatory system was chosen as the focus of the study, supported by the problem-based learning method and pop-up books to enhance learning motivation and critical thinking skills.

MATERIALS & METHODS

The type of research used in this study is research and development (R&D) using the ADDIE (Analysis, Design, Develop, Implement, and Evaluate) approach. ADDIE design is based on behaviorism, construction, social learning, and cognitivism and is student-centered (Branch, 2009:5). ADDIE was chosen as the research development model to produce the pop-up book product because the stages involved are simple yet systematic in implementation. The five stages in the ADDIE model provide opportunities for consistent product revision and evaluation, thus making the resulting product more valid and reliable. The following is a conceptual illustration of the stages of media development using the ADDIE model, presented in the figure below. Write here procedure/technique of your research study.

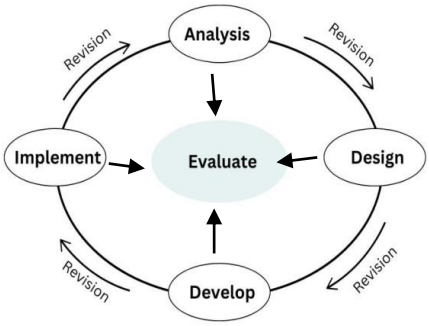

Figure 1 ADDIE Development Concept

The subjects of this study were eighth-grade students at MTs Al Fithrah Meteseh Semarang in the even semester of the 2025/2026 academic year. The research sample consisted of 60 students divided into two classes. The sample selection was carried out using a purposive sampling technique, namely a sampling technique based on certain considerations relevant to the research objectives. Data collection techniques were carried out using observations, interviews, and questionnaires to obtain the required information. Analysis was carried out by processing the data that had been obtained. The data analyzed in this study were the results of pop-up book media validation from media experts, material experts, and science teachers; data on student learning motivation; data on student critical thinking ability tests; and teacher and student responses to the use of pop-up book learning media.

RESULT and DISCUSSION

Characteristics of Problem-Based Learning Pop-up Books

The primary objective of developing this media is to increase learning motivation, strengthen conceptual understanding, and train students' critical thinking skills. The target audience is eighth-grade junior high school (SMP/MTs) students in Phase D of the Independent Curriculum, so the content and design of this pop-up book have been aligned with applicable science learning outcomes. Therefore, this pop-up book is expected to be a valid, practical, and effective learning medium to support science learning, particularly in the circulatory system. To clarify the main characteristics of this problem-based learning pop-up book, a summary is presented in table form, summarizing its physical aspects, content, features, and its relationship to the independent curriculum. Observations/Results of your study should be written in this section along with tables/charts/figures etc. write serial numbers and appropriate heading/title of tables and legend/caption of figures.

Number	Characteristics
1	Print media with interactive pop-up elements (3D heart, raised blood vessels, 3D blood cells).
2	Content based on real problems that are close to the lives of eighth-grade teenagers.
3	Problem-based prompt questions on each page to encourage critical thinking.
4	Supporting features include educational cartoon illustrations, a glossary of terms, PBL-based questions, video barcodes, and student reflection activities.
5	Arranged according to the science learning outcomes in Phase D of the Independent Curriculum.

The characteristics summarized in the table above are then concretely realized in the appearance of each page of the pop-up book. Each page is designed with distinctive pop-up visuals, problem scenarios relevant to the lives of teenagers, critical questions to spark discussion, and video barcode support to reinforce understanding. Therefore, the following description will detail how these characteristics are applied to the six main pages of the pop-up book.

Page 1 – Introduction

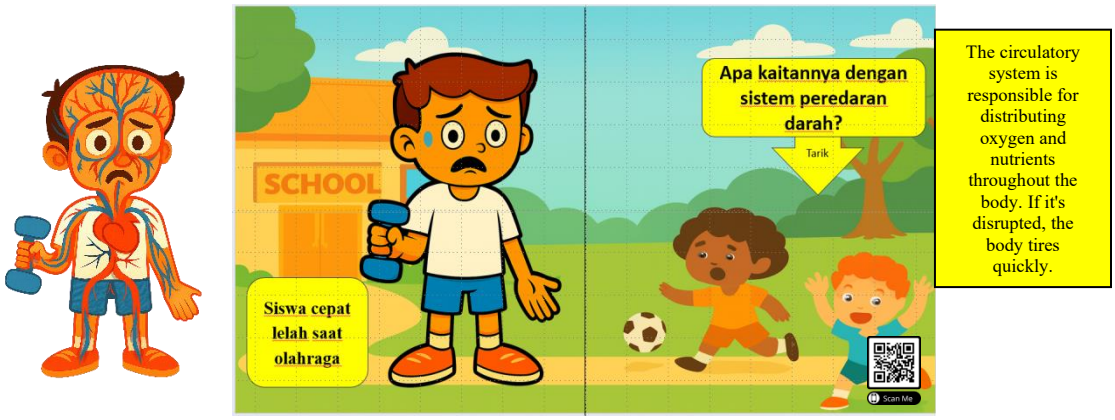

Figure 2 Page View one

The visualization on the first page features a boy with a transparent body. A pop-up image shows the arteries in red and veins in blue from head to toe. The background is depicted as a schoolyard, where other children are exercising. The pop-up effect makes the blood vessels appear to protrude from the child's body, allowing students to directly observe how the circulatory system works.

The problem scenario addressed concerns a student who tires quickly during exercise. The critical question asked is, "How does this relate to the circulatory system?" The material description explains that the circulatory system is responsible for distributing oxygen and nutrients throughout the body, so when there is a disruption, the body tires more quickly. To reinforce understanding, this page is equipped with a video barcode that students can scan. The barcode links to educational videos about the circulatory system available on YouTube. These videos serve as additional learning resources that help students deepen the material independently and avoid misconceptions.

Page 2 – Heart

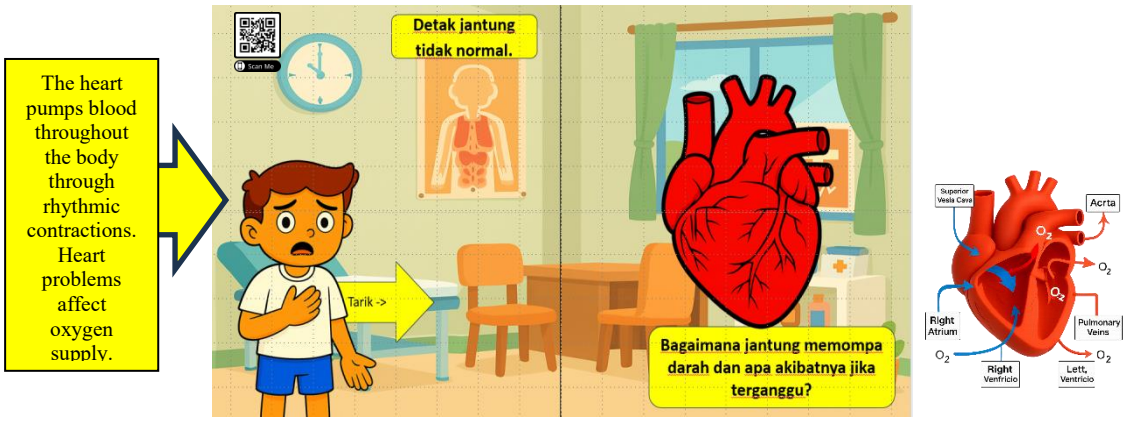

Figure 3 Page view two

The visualization on the second page shows a three-dimensional heart in red. The pop-up section is designed to open the heart, revealing the atria and ventricles, along with captions explaining their function. A boy is depicted holding his chest with a worried expression, providing appropriate visual context for the problem scenario.

Page 3 – Blood Vessels

Figure 4: Page Three

The visualization on the third page displays arteries and veins with distinct pathways, made prominent through a pop-up effect. This pop-up depicts a heart connected by red arteries and blue veins that spread throughout the body. A child is depicted with a cut on his hand, with blood flowing more rapidly from the artery, providing a concrete illustration of the different characteristics of blood vessels.

Page 4 – Blood Components

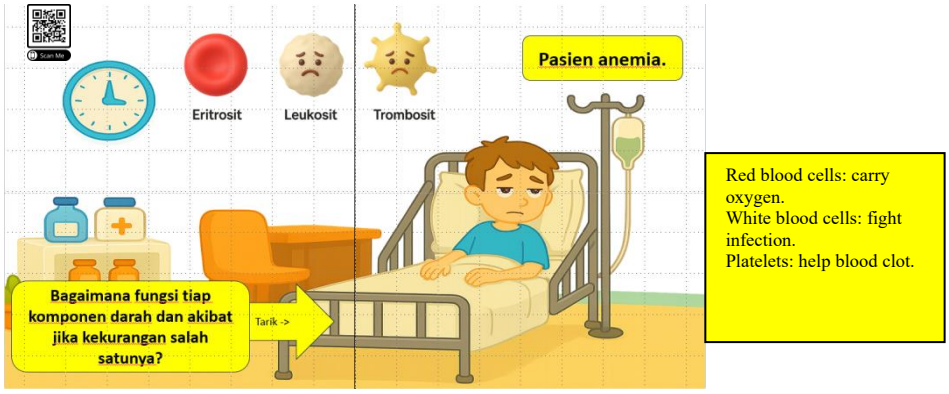

Figure 5 Page view four

The visualization on the fourth page displays red blood cells, white blood cells, and platelets in three dimensions through a pop-up effect. This pop-up is designed to clearly show each blood component, each with a distinct shape corresponding to its function. A child is depicted lying limp in a hospital bed, providing a realistic illustration of the condition of an anemia patient.

Page 5 – Small and Large Circulation

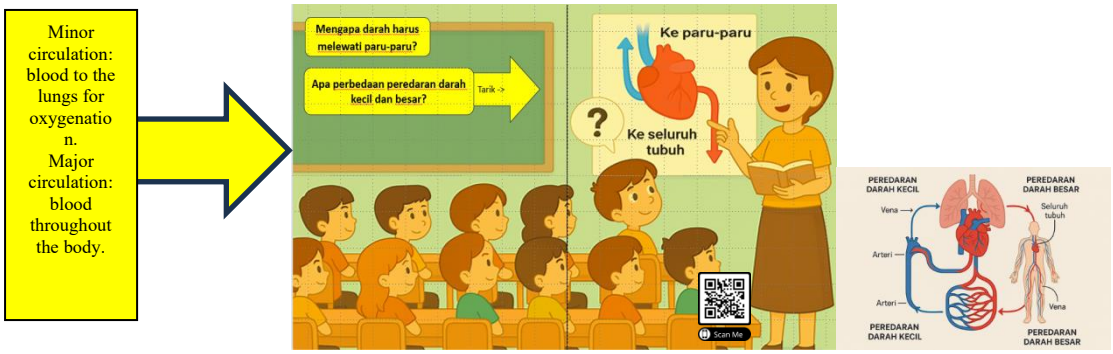

Figure 6: Page Five

The visualization on page five displays a diagram of blood flow to the lungs and throughout the body with red and blue arrows. A pop-up effect makes the blood circulation pathways visible, allowing students to clearly distinguish between small and large circulations. A child is depicted asking a question to the teacher while pointing to the diagram, providing an interactive context appropriate to the learning process.

Page 6 – Reflection

Figure 7 View of Page Six

The visualization on the sixth page displays a child's body complete with healthy lifestyle icons, such as eating fruit, exercising, getting enough sleep, drinking water, and not smoking. A pop-up effect makes these icons appear raised around the child's body, allowing students to easily identify habits that support a healthy circulatory system. A child is depicted discussing with the teacher while pointing to healthy lifestyle icons, providing an interactive context appropriate to the learning process.

Pop-up books have characteristics that emphasize the role of interactive print media in Phase D science learning. Pop-up elements featuring a 3D heart, raised blood vessels, and three-dimensional blood cells provide a concrete visual experience. Research by Anindita and Wardani (2024) shows that pop-up media improves thematic learning outcomes because they provide a more realistic learning experience. Research by Kim and Lee (2020) confirms that three-dimensional visualizations strengthen student engagement and help them develop deeper conceptual understanding. These interactive elements make learning more contextual and appropriate to students' cognitive developmental stages. Content based on real-life problems relevant to adolescents' lives makes learning more meaningful. Hafida and Nuryanto (2024) found that integrating pop-up books with the problem-based learning model improved students' ability to understand texts and

relate them to everyday experiences. A study by Barrows (2022) emphasized that problem-based learning encourages students to think critically and reflectively, enabling them to connect scientific concepts to real-life situations. Thus, pop-up books not only convey information but also train students to develop analytical and evaluation skills.

Pop-up Book Validity

Pop-up Book ValidityA validity test was conducted to determine the feasibility of the problem-based learning (PBL)-based pop-up book media before its implementation in learning. Validation was conducted by three validators, consisting of a science subject matter expert and a learning media expert. The validation results from both expert groups are shown in the table below.

Table 2 Results of Validation by Material Experts

Rated aspect	Maximum Score	Validator 1	Validator 2	Validator 3	Average (%)	Criteria
Content alignment with the curriculum	5	5	4	5	0,93	Very Eligible
Circulatory system concept accuracy	5	5	5	5	1,00	Very Eligible
Relationship with critical thinking indicators	5	5	5	4	0,93	Very Eligible
Relevance to the PBL approach	5	4	5	5	0,93	Very Eligible
Total	**20**	**19**	**19**	**19**	**0,95**	Very Eligible

Table 3 Media Expert Validation Results

Rated aspect	Maximum Score	Validator 1	Validator 2	Validator 3	Average (%)	Criteria
Visual Design	5	4	5	5	0,93	Very Eligible
Construction Quality	5	5	5	4	0,93	Very Eligible
Interactivity	5	5	5	5	1,00	Very Eligible
Suitability to Junior High School Student Characteristics	5	5	5	4	0,93	Very Eligible
Total	**20**	**19**	**19**	**18**	**0,95**	Very Eligible

Based on the validation results from material experts, the PBL-based pop-up book received an average score of 0.95 (95%), categorized as very appropriate. The accuracy of the circulatory system concept received a full score (100%), indicating that the material presented is scientifically sound and aligned with the curriculum. The aspects of content suitability, relevance to critical thinking indicators, and relevance to PBL each received a score of 93%, confirming that this media is relevant to the objectives of problem-based science learning.

The validation results from media experts also showed an average score of 0.95 (95%), categorized as very appropriate. The interactivity aspect received a full score (100%), confirming that this media is able to encourage active student engagement. The aspects of visual design, construction quality, and suitability to the characteristics of junior high school students each received a score of 93%, indicating that the pop-up book has an attractive appearance, good construction, and is appropriate to student needs. This demonstrates that the developed media not only presents information but also supports the achievement of 21st-century skills, particularly critical thinking skills. These findings align with research by Hana Carolin and Firosalia Kristin (2024), which demonstrated that pop-up books are valid and effective in improving elementary school students' science learning outcomes through validity tests and student responses.

These findings align with research by Ardini, Wayudi, and Wahyono (2025), which confirmed that implementing PBL with pop-up books improves elementary school students' learning motivation and mathematics learning outcomes.

Theoretically, these validation results support the grand theory of constructivism, which emphasizes that knowledge is actively constructed through meaningful learning experiences. PBL-based pop-up books provide concrete visual experiences that strengthen students' analytical and reflective processes in solving real-life problems. Furthermore, these findings are relevant to Self-Determination Theory (SDT), as the media supports competency through visualizations that facilitate understanding, autonomy through the freedom to explore problems in PBL, and relatedness through group discussions. This is consistent with research by Qothrunnada et al. (2025), which analyzed the validity and reliability of the multimodal PBL model and found that a problem-based approach can improve both digital literacy and critical thinking skills in students.Practically, the high validation results indicate that PBL-based pop-up books are feasible for implementation in circulatory system learning in Indonesia. This media can be a solution for teachers to create more interactive, engaging, and effective learning while also supporting the achievements of the independent curriculum, which emphasizes critical thinking and problem-solving skills.

Practicality of Pop-Up Books

The practicality of the learning media was analyzed through teacher and student responses in the control class using worksheets (LKPD) and the experimental class using pop-up books based on learning (PBL). Aspects assessed included the media's suitability to science learning objectives, ease of use, potential for improving critical thinking skills and learning motivation, suitability to student characteristics, and support for PBL implementation in the classroom.

Table 4 Comparison of Practicality of LKPD (Control) and Pop-up Book (Experiment) Based on Teacher Responses

Practicality Aspect	**Control Class (LKPD))**	**Criteria**	**Experimental Class (Pop up book)**	**Criteria**
The media aligns with the science learning objectives for the circulatory system.	100%	Good	100%	Very good
The media is easy to use in the learning process.	80%	Good	100%	Very good
The media has the potential to improve students' critical thinking skills.	60%	Good	80%	Very good
The media has the potential to increase students' learning motivation.	80%	Good	100%	Sangat Baik
The media is appropriate for the characteristics of junior high school students.	60%	Good	100%	Very good
The media supports the implementation of Problem-Based Learning in the classroom.	60%	Good	100%	Very good
Average	**73,3%%**	**Good**	**96,7%**	**Very good**

Table 5 Comparison of Practicality of LKPD (Control) and Pop-up Book (Experiment) Based on Student Responses

Practical Aspects	**Control Class (LKPD))**	**Criteria**	**Experimental Class (Pop up book)**	**Criteria**
The media aligns with the science learning objectives for the circulatory system.	71%	Good	91%	Very good
The media is easy to use in the learning process.	69%	Good	93%	Very good

The media has the potential to improve students' critical thinking skills.	67%	Good	92%	Very good
The media has the potential to increase students' learning motivation.	67%	Good	87%	Very good
The media aligns with the characteristics of junior high school students.	69%	Good	90%	Very good
The media supports the implementation of Problem-Based Learning in the classroom.	69%	Good	93%	Very good
Average	**67,7%%**	Good	**91,2%**	**Very good**

The analysis of teacher responses showed that PBL-based pop-up books were more practical to use than student worksheets (LKPD). Teachers considered this medium more aligned with science learning objectives (100%, very good), easier to use (100%, very good), and more supportive of PBL implementation in the classroom (100%, very good). The aspects with the lowest scores on the LKPD were suitability to student characteristics and support for PBL, each with only 60% in the good category. Conversely, pop-up books received a perfect score (100%) in almost all aspects, with an average of 96.7% in the very good category, while LKPD received only 73.3% in the good category. This confirms that teachers consider pop-up books more relevant, practical, and effective in supporting problem-based science learning.

Student responses are also consistent with teacher assessments. Students considered pop-up books more engaging, easier to use, and more suited to their characteristics as junior high school students. The aspects with the highest scores were ease of use (93%, very good) and support for PBL (93%, very good). Furthermore, pop-up books were deemed more effective in improving critical thinking skills (92%) and learning motivation (87%) compared to student worksheets (LKPD), which only scored 67% in both aspects. Students rated the pop-up books' average practicality score at 91.2%, categorized as very good, while LKPD only scored 67.7%, categorized as good.

These results indicate that pop-up books are more aligned with science learning objectives, easier to use, and more supportive of PBL implementation than student worksheets (LKPD), which only received an average score of "good." These findings align with research by Anindita & Wardani (2025), which confirmed that pop-up books are valid and effective in improving thematic learning outcomes, especially when integrated with problem-based strategies.

From the teacher's perspective, pop-up books are considered more practical because they present material on the circulatory system visually and interactively, thus facilitating the learning process. This is consistent with the findings of Mardiyah et al. (2024), who stated that interactive visual-based media can reduce the dominance of lecture methods and increase active student participation. Meanwhile, students considered pop-up books more engaging and suited to their characteristics as learners. Research by Hwang & Chen (2022) also supports these findings, stating that the integration of interactive visual media in PBL increases student engagement and the effectiveness of science learning. Pop-up books have been shown to be more effective in improving critical thinking skills and learning motivation than conventional books. This reinforces the findings of Norra et al. (2019), and Lestari (2020) demonstrated that pop-up books can improve learning motivation and critical thinking skills through engaging and contextual three-dimensional visualizations. Thus, the practicality of pop-up books lies not only in their ease of use but also in their ability to support the achievement of science learning objectives oriented toward developing 21st-century skills.

Influence on Learning Motivation

The analysis of student learning motivation was conducted using the ARCS (Attention, Relevance, Confidence, Satisfaction) instrument. The results of the calculation of the percentage of learning motivation before and after learning in the control class (LKPD) and the experimental class (PBL-based Pop-up Book) are shown in Table 6 below.

Table 6: Comparison of Student Learning Motivation in the Control and Experimental Classes

Motivational Indicator	Pre Test Control (%)	Post Test Control (%)	Category	Pre-Test Experiment (%)	Post Test Experiment (%)	Category
Attention	43	89,0	Good → Very Good	41,0	93,0	Good → Very Good
Relevance	44,7	83,0	Good → Very Good	38,3	93,5	Good → Very Good
Confidence	43,5	89,2	Good → Very Good	40,3	93,0	Good → Very Good
Satisfaction	43,3	85,8	Good → Very Good	42,7	92,2	Good → Very Good
Total Average	**43,6**	**86,6**	**Good → Very Good**	**40,5**	**92,9**	**Good → Very Good**

Student learning motivation before the lesson in both classes was still in the adequate category. This is evident from the average score of 43.6% for the control class and 40.5% for the experimental class. These relatively low scores indicate that before the treatment, students lacked optimal attention, relevance, confidence, and learning satisfaction. This is understandable, as previous instruction still used conventional methods that tended to be teacher-centered. Therefore, it can be said that students' initial motivation had not yet developed optimally and required intervention with more engaging and contextual learning media.

After the lesson, learning motivation increased in both classes. In the control class, which used student worksheets (LKPD), the average learning motivation increased from 43.6% to 86.6%, shifting the category from adequate to excellent. This improvement indicates that student worksheets (LKPD) remain effective in stimulating learning, although they are still limited in their ability to capture attention and maximize learning satisfaction. Students felt more focused with the use of student worksheets, but their active engagement in discussions and problem-solving was not yet optimal.

Table 7: Independent Samples Test (Experimental Posttest vs. Control)

Group	N	Mean Posttest	Std. Deviation	t	df	Sig. (2-tailed)
Experimental	30	92,94	2,084	8,158	58	,000
Control	30	86,65	3,678	8,158	45,872	,000

The experimental class' posttest average of 92.94 was higher than the control class's score of 86.65. The Sig. (2-tailed) value of 0.000 < 0.05 indicates a significant difference in learning motivation between the two classes. Therefore, it can be concluded that PBL-based pop-up books are more effective than student worksheets (LKPD) in increasing student learning motivation.

A comparison between the two classes shows that although LKPD can increase learning motivation, PBL-based pop-up books provide more optimal results. This medium not only presents material visually and interactively but also supports problem-based learning syntax that encourages students to actively discuss, analyze, and find solutions. Therefore, PBL-based pop-up books are superior in increasing learning motivation compared to LKPD. This

difference also indicates that the use of innovative media appropriate to the characteristics of junior high school students can have a significant impact on their engagement in science learning.

These findings align with the ARCS theory developed by Keller (2023), which emphasizes that attention, relevance, confidence, and satisfaction are key factors in building learning motivation. Interactive visual-based media have proven to be more effective in meeting these four aspects than student worksheets (LKPD). Overall, the results of this study confirm that PBL-based pop-up books have a positive and significant impact on student learning motivation. This media not only increases motivation scores quantitatively but also reflects students' active involvement in the learning process. Research conducted by Deci & Ryan (2024) within the Self-Determination Theory framework supports these findings, stating that students' intrinsic motivation increases when their basic psychological needs are met through engaging and relevant learning. Therefore, PBL-based pop-up books are worthy of being an alternative innovative learning medium to increase science learning motivation, particularly in the circulatory system, as well as supporting the achievement of 21st-century competencies that emphasize critical thinking, collaboration, and problem-solving skills.

Impact on Critical Thinking

The analysis of students' critical thinking skills was conducted using a test instrument consisting of five indicators: simple explanations, basic skills (data/facts), inferences, advanced explanations (analysis), and strategies and tactics (solutions). The results of the calculation of the percentage of critical thinking skills before and after learning in the control class (LKPD) and the experimental class (PBL-based Pop-up Book) are shown in the table below.

Table 8 Comparison of Critical Thinking Skills of Students in the Control and Experimental Classes

Critical Thinking Indicators	**Pre Test Control (%)**	**Post Test Control (%)**	**Category**	**Pre-Test Experiment (%)**	**Post Test Experiment (%)**	**Category**
Simple explanation	63	85	Good → Very Good	56	97	Good → Very Good
Basic skills (data/facts)	52	87	Good → Very Good	50	92	Good → Very Good
Conclusion	47	80,7	Good → Very Good	45	90	Good → Very Good
Further explanation (analysis)	44	70	Good → Very Good	35	94	Good → Very Good
Strategy and tactics (solutions)	21	57	Good → Very Good	20	93	Good → Very Good
Average Total	**45,3**	**75,87**	**Good → Very Good**	**41,2**	**93,1**	**Good → Very Good**

Based on the table above, students' critical thinking skills in the control class (LKPD) increased from an average of 45.3% (sufficient) in the pre-test to 75.87% (good) in the post-test. This improvement indicates that the LKPD is able to help students understand the basic concepts of the circulatory system and develop analytical skills. However, the improvement did not reach the excellent category, particularly in the strategy and tactics indicator, which only increased from 21% to 57%. This indicates that the LKPD is not yet fully capable of training students in developing creative and applicable solutions to real-life problems.

Meanwhile, in the experimental class, which used pop-up books based on problem-based

learning, the improvement in critical thinking skills was more significant. The average score increased from 41.2% (sufficient) to 93.1% (very good). The most significant improvements occurred in the simple explanation indicator (from 56% to 97%) and strategy & tactics (from 20% to 93%).

This suggests that PBL-based pop-up books are more effective in training students to think systematically, evaluate information, and make informed decisions. Research by Imaduddin & Damayanti (2025) confirms that the use of PBL-based pop-up books in science learning can improve critical thinking skills because engaging three-dimensional visualizations make students more active and engaged in the learning process. This finding is further supported by research by Hwang & Chen (2022), which states that integrating interactive visual media with PBL increases student engagement in science learning and strengthens analytical skills.

A comparison between the control and experimental classes shows that while student worksheets (LKPD) can improve critical thinking skills, PBL-based pop-up books provide more optimal results. This medium not only presents material visually but also supports PBL syntax, encouraging students to actively discuss, analyze, and evaluate information. Research by Solihah & Bintaro (2023) shows that implementing PBL with pop-up books can improve motivation and science learning outcomes, while also strengthening critical thinking skills.

CONCLUSION

The developed pop-up book has attractive, interactive, and contextual three-dimensional visual characteristics. This media is designed according to the circulatory system material, supports PBL syntax, and adapts to the characteristics of students so that learning is more meaningful and student-centered. Validation results by material experts, media experts, and science teachers show that the pop-up book meets the criteria for eligibility of content, appearance, and readability in a very valid category. In addition, the results of the trial in the experimental class showed a significant increase in student learning motivation. A questionnaire based on ARCS theory showed that pop-up books were able to attract attention, increase the relevance of the material to everyday life, foster self-confidence, and provide higher learning satisfaction than LKPD. Statistical tests confirmed that PBL-based pop-up books had a significant effect on developing critical thinking skills compared to learning with LKPD. This proves that the media is suitable for use in science learning.

Declaration by Authors

Acknowledgement: None

Source of Funding: None

Conflict of Interest: No conflicts of interest declared.

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How to cite this article: Lilik Fajriyah, Dyah Rini Indrayanti. Development of a pop-up book based on problem-based learning to improve students' learning motivation and critical thinking abilities. *International Journal of Research and Review*. 2026; 13(4): 646-659. DOI: *https://doi.org/10.52403/ijrr.20260466*

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