



Development of Circulatory System Puzzle Media to Improve Students' Collaboration Skills and Cognitive Learning Outcomes

Ika Sulistyowati¹, Siti Zubaidah^{2*}, Feni Tin Faizah³

^{1,2*}Department of Biology, Universitas Negeri Malang, Indonesia.

³SMA Negeri 2 Batu, Kota Batu, Indonesia.

*Corresponding Author. Email: siti.zubaidah.fmipa@um.ac.id

Abstract: This study aims to develop valid, practical, and effective CIZLE media for improving students' collaboration skills and cognitive learning outcomes. The development process followed the ADDIE model. The participants were 29 students from Class XI BIO 4 at SMA Negeri 2 Batu. The study employed a pre-experimental one-group pretest-posttest design integrating Problem-Based Learning (PBL). Data were collected using a collaboration skills questionnaire, an observation sheet, and cognitive pretest and posttest instruments. The data were analyzed using either the Wilcoxon signed-rank test or paired-samples t-test, N-Gain, and Cohen's d. CIZLE achieved validation scores of 100% from subject-matter and media experts and 92% from educational practitioners, while its practicality score reached 90%. Collaboration questionnaire scores increased from 73 to 85 (N-Gain = 0.5130; d = 0.99), observation scores increased from 45 to 88 (N-Gain = 0.8110; d = 4.12), and cognitive learning outcome scores increased from 54 to 92 (N-Gain = 0.8304; d = 1.34). Pedagogically, CIZLE integrated with PBL can be adapted to abstract biology topics by incorporating puzzle components that represent biological structures, processes, and relationships.

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Introduction

Collaboration is an essential 21st-century skill that significantly affects learning quality (Setiawan *et al.*, 2026). It involves working together and respecting differing opinions to reach shared decisions, enabling students to address work-related challenges (Francisco *et al.*, 2024; Greenstein, 2012). A questionnaire among 12th-grade students at SMA Negeri 2 Batu showed that 51.4% struggle to collaborate effectively, as shown by low responsibility and contribution. Students often remain passive in groups (Hussein, 2021). Thus, collaboration skills need improvement through discussions and group activities (Putri *et al.*, 2025).

Low collaboration indicates a need for improvement in the learning process, as it significantly affects learning outcomes (Marita *et al.*, 2023). Students' involvement in group discussions is an important factor in achieving learning outcomes, especially cognitive outcomes (Mulyadi *et al.*, 2023). Students with high collaboration skills tend to show higher cognitive learning outcomes as well, because collaboration predicts changes in cognitive learning outcomes (Ilma & Sam, 2024).

Cognitive aspects are a measure of learning success because they reflect changes in students' intellectual abilities after learning (Anderson & Krathwohl, 2001). Low cognitive learning outcomes indicate that learning has not been optimal, especially in science learning (Kristiani *et al.*, 2023). The students' questionnaire results show that 48.6% of students still



need to improve their cognitive learning outcomes because the material is complex (70.3%), focuses on concepts (67.6%), is difficult to apply (54.1%), and learning is ineffective (64.9%).

Low collaboration and cognitive learning outcomes are partly due to the implementation of suboptimal learning models (Pattipeilohy *et al.*, 2022). One innovative learning model relevant to improving collaboration skills and cognitive learning outcomes is Problem-Based Learning (PBL) (Granado-Alcón *et al.*, 2020). Students play a central role in learning through group problem-solving activities (Arends, 2014). Through the PBL model, students can learn the topics and solve problems with group members (Robi *et al.*, 2024).

PBL can facilitate optimal group discussions, thereby reducing conflicts during problem-solving (Usman *et al.*, 2024). Research by Hidayati *et al.* (2023) shows that PBL can improve students' collaboration skills and cognitive learning outcomes by fostering active student-to-student exchange of ideas. However, the effectiveness of PBL is not solely determined by syntax but also by media innovations that support investigation and exploration activities (Juniantari & Suniasih, 2023).

Material's complexity contributes to low collaboration and cognitive learning outcomes. The 11th-grade Circulatory System material is difficult because it covers structure, function, disorders, and treatment technologies (Rusdi *et al.*, 2022). Students struggle to understand concepts, terms, and mechanisms (Yaumi & Rohmah, 2024). Thohir *et al.* (2022) stated that students' low understanding was influenced by limited innovation in learning media. The students' questionnaire shows that 75.7% find it difficult to learn this material due to its complexity, boring methods, and media that do not engage students in collaboration.

Implementing PBL requires appropriate learning media. The media commonly used in biology learning are limited to PowerPoint, images, and videos (Putri *et al.*, 2024). The development of innovative media is needed to increase students' engagement, thereby improving collaboration skills and cognitive learning outcomes (Puriadi & Surnjono, 2024). One such innovation is game-based media, which has a real impact on students' lives, making it suitable for learning rather than entertainment (Punyasettro & Yasri, 2021).

Game-based media that has the potential to increase students' interest is puzzles (Putra *et al.*, 2025). Puzzles are not just about arranging picture pieces; they involve problem-solving processes (Mahdi *et al.*, 2020). Kharomah *et al.* (2024) demonstrated that puzzle-based case studies help implement the Teams Games Tournament (TGT) model and are effective in improving cognitive learning outcomes for high school students in respiratory system material. Puzzles also help implement the PBL model through collaborative problem-solving activities (Oktavia *et al.*, 2024).

The development of puzzle media for Circulatory System material is needed as a tool to assist in the implementation of PBL to improve collaboration skills and cognitive learning outcomes. This is supported by the results of a needs analysis of 12th-grade students, which shows that biology lessons at SMA Negeri 2 Batu have never used puzzle media. This condition has led 94.5% of students to express interest in learning about the Circulatory System through puzzle-based media, as it makes learning more engaging and enjoyable.

To address low collaboration and cognitive learning outcomes, the Circulatory System Puzzle (CIZLE) media was developed as a problem-based puzzle to assist PBL implementation. CIZLE was integrated into PBL as a learning media that supports students' investigation and collaborative problem solving. Specifically, during the investigation phases of PBL, students worked collaboratively to discuss the circulatory system problem and answer questions provided through CIZLE. Each correct answer allowed students to obtain a



puzzle piece, which they combined to construct a complete puzzle. This mechanism encouraged students to exchange ideas, analyze information, and connect relevant concepts while working toward a solution. The completed puzzle then served as a learning product that supported students' presentation and reflection in the PBL phases.

Research Method

This study employed the ADDIE development model as illustrated in Figure 1 by (Branch, 2009), conducted at Malang State University from July to December 2025. The needs analysis involved Grade XII BIO 2 students who had studied the Circulatory System and a biology teacher. The design and development phases involved preparing instructional materials, research instruments, and CIZLE media using *Canva*, followed by validation by subject matter experts, media experts, and education practitioners and practicality testing with teachers and students. The scores obtained from the media validity and practicality tests are calculated using Formula (1) (Septiani & Okmarisa, 2023), then categorized into the criteria illustrated in Table 1.

The implementation integrated CIZLE into PBL over three meetings using a pre-experimental one-group pretest-posttest design. Effectiveness was evaluated using collaboration skill questionnaires and observations and cognitive pretest and posttest scores. Effectiveness scores were calculated using Formula (1). Collaboration skill percentages and criteria followed by (Greenstein, 2012) and illustrated in Table 2. Data were tested for Paired Sample T-Test or the Wilcoxon test with a p-value of 0.05 (Anam, 2020). The data were analyzed using the N-Gain and then categories that presented in Table 3, followed by an effect size analysis using the categories presented in Table 4.

$$P = \frac{n}{N} \times 100\% \quad (1)$$

Description:

P= percentage

n= total score obtained

N= maximum total score

Table 1. Criteria for Media Validity and Practicality

(Adapted from Hinkle *et al.*, 2003))

Percentage (%)	Criteria
100	Very valid and very practical, can be used without revision
$80 \geq X < 99$	Valid and practical, can be used with minor revisions
$60 \geq X < 79$	Quite valid and quite practical, revision in progress
$40 \geq X < 59$	Invalid and not practical enough, major revision
$0 \geq X < 39$	Not valid and not practical at all, not used

Table 2. Percentage and Criteria for Collaboration Skills

Percentage (%)	Scale	Criteria
0-25	1	Novice
26-50	2	Basic
51-75	3	Proficient
76-100	4	Exemplary

Table 3. N-Gain Criteria

(Adapted from Hake, 1998)

N-Gain	Interpretation
$g > 0.70$	High



$0.30 \leq g \leq 0.70$	Moderate
$g < 0.30$	Low
Table 4. Effect Size (Adapted from Cohen, 2013)	
N-Gain	Interpretation
$g > 0.70$	High
$0.30 \leq g \leq 0.70$	Moderate
$g < 0.30$	Low

Results and Discussion

Analyze

The needs analysis indicates that students' collaboration skills on the Circulatory System topic remain suboptimal, with achievement rates of 2.7% (novice) for productive work, 73% (proficient) for mutual respect, 21.6% (novice) for compromise, and 37.8% (basic) for responsibility. Additionally, 32% of students have not reached the minimum score, mainly due to insufficient learning media. Survey data show that 59.5% of students support game-based media and 48.6% favor puzzle-based media. Teachers also confirmed that puzzle media has never been used in biology. These findings support the development of CIZLE to enhance students' collaboration skills and cognitive learning outcomes.

Design

The design phase involved developing instructional materials, research instruments, storyboards, and validation sheets. CIZLE was designed for the Circulatory System topic by integrating problem-based questions about real-life disorders with puzzle components, where correct answers yield complete images and incorrect answers result in incomplete images. The learning objective was for students to analyze the types, causes, and preventive measures of Circulatory System disorders. CIZLE and its instructional tools were validated by media experts, subject matter experts, education practitioners, lecturers, and biology teachers. Practicality was assessed through teacher and student questionnaires, while effectiveness was evaluated using collaboration skills questionnaires and observations and pretest and posttest results. The design phase evaluation emphasized improving the layout of images and text on the puzzle components to enhance readability and usability.

Develop

The development phase commenced with the creation of content, including the CIZLE media and its components, as illustrated in Figure 1. CIZLE was developed utilizing the Canva application and is accompanied by instructional guides for both students and teachers to support effective implementation. The completed CIZLE media subsequently underwent formative revision, which involved validation conducted by subject matter experts, media experts, and education practitioners. The results of these validations are illustrated in Tables 5, 6, and 7, respectively.



Figure 1. CIZLE Media

Subject matter experts validation is intended to assess the alignment of the developed media's content with established criteria (Husniah *et al.*, 2020). As illustrated in Table 5, subject matter experts validation of the CIZLE media demonstrated 100% validity, meeting the criteria for very valid. Therefore, the CIZLE media fulfills required standards and is suitable for instructional use.

Table 5. Results of Media Validation Conducted by Subject Matter Experts

Assessment Criteria	Validity Percentage	Validation Criteria
Content Coverage	100	Very valid
Content Appropriateness	100	Very valid
Language Quality	100	Very valid
Average	100	Very valid

Media validation by media experts is intended to evaluate the quality of the media in terms of product usability (Febrianti *et al.*, 2022). As illustrated in Table 6, the CIZLE media attained a validity score of 100%, meeting the criteria for very valid. Therefore, the CIZLE media satisfies quality standards for product usability and is appropriate for instructional use.

Table 6. Results of Media Validation Conducted by Media Experts

Assessment Criteria	Validity Percentage	Validation Criteria
Layout (including size and cover)	100	Very valid
Graphic Quality	100	Very valid
Content Accuracy	100	Very valid
Language Quality	100	Very valid
Average	100	Very valid

Validation by education practitioners is intended to assess the suitability and usefulness of the media based on the practitioners' professional experience with predetermined aspects (Mulder *et al.*, 2023). Based on Table 7, the validity of the CIZLE media, as assessed by education practitioners, was determined to be 92%, which falls within the valid criteria. Therefore, the CIZLE media fulfills practicality standards and is appropriate for instructional use.

Table 7. Results of Media Validation Conducted by Education Practitioners

Assessment Criteria	Validity Percentage	Validation Criteria
Appropriateness of the Material	92	Valid
Clarity of the Questions	94	Valid
Suitability for Enhancing Collaboration Skills	90	Valid
Suitability for Enhancing Cognitive Learning Outcomes	90	Valid
Average	92	Valid



The validated CIZLE media was subsequently tested to assess user responses and determine its practicality. The results of the CIZLE media practicality test are illustrated in Table 8. Based on Table 8, the average practicality percentage of the CIZLE media was 90%, which falls within the practical category. Therefore, the CIZLE media fulfills both practicality and validity criteria and is suitable for use in the implementation phase.

Table 8. Results of the CIZLE Media Practicality Test

Phase	Practicality Percentage	Validation Criteria
One-to-One Trial	83	Practical
Small Group Trial	89	Practical
Field Trial	91	Practical
Biology teacher responses	95	Practical
Average	90	Practical

The evaluation conducted during the develop phase included adding a sequential arrangement of answer card positions on the acrylic board to correspond with the question numbers, thereby facilitating the use of the CIZLE media. Additionally, the shapes of the puzzle pieces were refined for improved neatness. The original circular pieces were replaced with triangles to simplify the cutting and assembly process.

Implement

The implementation was conducted in Grade 11 BIO 4 at Batu State High School 2, involving 36 students. CIZLE media was integrated into the PBL model, particularly during student organization and investigative phases. Implementation began with a pretest and concluded with a posttest on the Circulatory System. Students also completed a collaboration skills questionnaire, while an observer assessed collaboration skills at both the start and end of the process. Data from pretests, posttests, questionnaires, and observations were analyzed to evaluate the effectiveness of CIZLE.

CIZLE Media for the Enhancement of Students' Collaboration Skills

The mean scores for students' collaboration skills are illustrated in Figure 2. Questionnaire results increased from 73 at the beginning to 85 at the end of CIZLE media implementation. Descriptive analysis showed data ranges of 12.89 and 14.24. The Kolmogorov-Smirnov normality test yielded a p-value < 0.05, indicating non-normal data. Consequently, the Wilcoxon Test was conducted, as illustrated in Table 9. Wilcoxon Signed-Rank Test results showed a significance value < 0.05, leading to the rejection of H₀ and indicating a significant difference in collaboration skills between the beginning and end, as measured by the questionnaire. These findings were further supported by the questionnaire results, which showed an N-Gain score of 0.5130, indicating a moderate level of improvement, with a Cohen's d of 0.99, indicating a large effect.

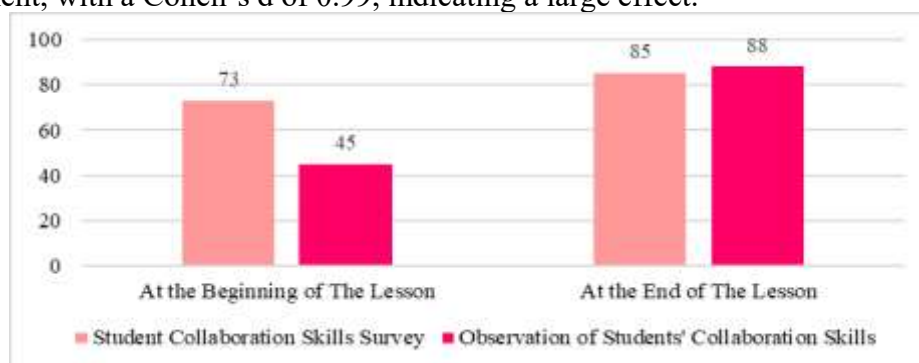


Figure 2. Mean Scores of Students' Collaboration Skills

Table 9. Wilcoxon Signed-Rank Test on the Questionnaire Data of Collaboration Skills

	P-value
Z	-4,112
Asymp. Sig. (2-tailed)	<0,001

Students' collaboration skills were also measured using an observational instrument. As illustrated in Figure 2, observations revealed a mean increase from 45 to 88. The mean results were analyzed descriptively, yielding standard deviations of 11.76 and 11.11. The normality test yielded a p-value < 0.05, indicating non-normal data. Therefore, the Wilcoxon test was conducted, with results presented in Table 10. The Wilcoxon Signed-Rank Test on the observational data showed a significance value < 0.05, indicating that H₀ was rejected. This indicates a significant difference in collaboration skills between the beginning and end of learning with the CIZLE media, as measured through observations. The observation of collaboration skills obtained an N-Gain score of 0.8110, indicating a high level of improvement, and a Cohen's d of 4.12, indicating a large effect.

Table 10. Wilcoxon Signed-Rank Test on the Observational Data of Collaboration Skills

	P-value
Z	-4,685
Asymp. Sig. (2-tailed)	<0,001

Based on the effectiveness test, the implementation of the CIZLE media was found to enhance students' collaboration skills. The CIZLE media was utilized in the second and third phases of PBL, as illustrated in Figure 3. This improvement is attributed to CIZLE's promotion of harmonious collaboration among students through engaging games. This finding is consistent with Anam *et al.* (2024), who state that group games facilitate students' understanding and active participation in discussions, thereby fostering interaction, tolerance, and collaboration within learning groups.



Figure 3. Students' Utilization of CIZLE

The tendency for students to rely on peers during group work can be mitigated through the use of game-based media, as each student is encouraged to contribute ideas and opinions when answering questions on CIZLE. Support for the implementation of PBL and enhanced collaboration is demonstrated by student questionnaire results and observer assessments at the beginning and end of the learning process. Thus, CIZLE improved the collaboration skills of Grade 11 BIO 4 students at SMA Negeri 2 Batu in the Circulatory System material.



CIZLE Media for the Enhancement of Students' Cognitive Learning Outcomes

The mean scores of the students' pretest and posttest are presented in Figure 4. Based on Figure 4, pretest and posttest scores increased from 54 to 92 following the implementation of the CIZLE media. The mean scores were analyzed descriptively, resulting in standard deviations of 30.22 and 13.97. Normality testing of pretest and posttest results yielded a p -value > 0.05 , indicating normal distribution. Accordingly, a Paired Sample T-test was conducted, with results illustrated in Table 11. Based on Table 11, a p -value < 0.05 was obtained. This result indicates that H_0 is rejected, demonstrating a significant difference between the pretest and posttest results. The pre-posttest obtained an N-Gain score of 0.8304 (high) and a Cohen's d of 1.34 (large effect), indicating that the implementation of CIZLE effectively improved students' cognitive learning outcomes.

Based on effectiveness tests, the CIZLE media has been shown to enhance students' cognitive learning outcomes by making learning more enjoyable and aiding the absorption of new information. These findings are consistent with those of Putri *et al.* (2025), who noted that puzzles as a learning medium foster enjoyment, facilitate material comprehension, and can improve cognitive outcomes. The effectiveness of CIZLE is further supported by the PBL model, which promotes problem-solving, develops higher-order thinking skills, and enhances students' cognitive learning outcomes (Lismayanti *et al.*, 2026; Putra *et al.*, 2026).

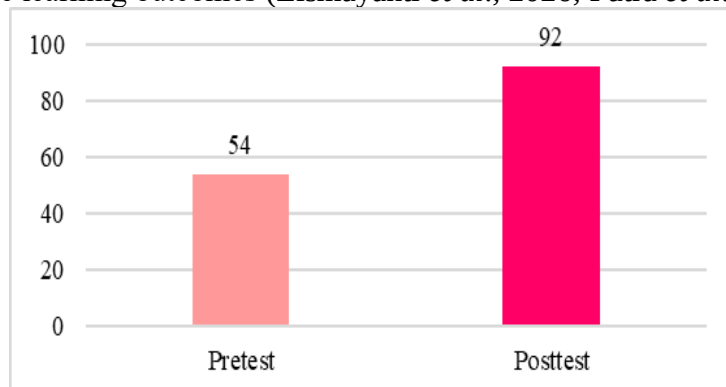


Figure 4. Mean Scores of Pretest and Posttest

Table 11. Results of the Paired Sample T-Test on Pretest and Posttest Scores

Paired Differences							
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
			Lower	Upper			
-38,21	28,55	5,39	-49,28	-27,14	-7,08	28	< 0,001

The Relationship Between PBL and Students' Collaboration Skills and Cognitive Learning Outcomes

PBL enhances students' collaboration skills by engaging them in all stages of problem-solving, from analyzing issues to formulating solutions. This is supported by Choirunisa *et al.* (2023), who found that PBL fosters these collaborative practices. The CIZLE platform and PBL together facilitate collaboration and make group work more engaging. (Afelia *et al.*, 2023) found that PBL creates a positive learning environment. Additionally, PBL improves cognitive learning outcomes through contextual problem-solving, while CIZLE increases students' interest and understanding of complex concepts. This finding aligns with Azizah *et al.* (2023), who reported improved cognitive outcomes with puzzle-assisted PBL.



The effectiveness of CIZLE may also be understood through the complementary roles of cognitive engagement and social interaction. The problem-solving process encourages students to construct meaning, while collaborative tasks provide opportunities to negotiate understanding and consider alternative perspectives. These processes may support deeper conceptual understanding and the development of collaboration skills. Therefore, the learning benefits of CIZLE may lie not merely in its game-based format, but in how its learning activities promote both individual thinking and collective knowledge construction.

Conclusion

The CIZLE media has been proven to be valid, practical, and effective in improving high school students' collaboration skills and cognitive learning outcomes in the Circulatory System subject. The validation results of the CIZLE media by subject matter experts reached 100% (very valid), by media experts reached 100% (very valid), and by education practitioners reached 92% (valid). The practicality test results reached 90% (practical). The effectiveness test results showed an increase in students' collaboration skills and cognitive learning outcomes. Pedagogically, the integration of CIZLE with PBL can be adapted to other abstract biology topics by representing complex structures, processes, or relationships through interconnected puzzle components, thereby providing students with a concrete learning experience while engaging them in problem-solving activities.

Recommendation

Recommendations for further research include developing puzzle media for other biology topics and implementing CIZLE with learning models beyond PBL. Teachers can adapt CIZLE to students' learning needs and the characteristics of different biology topics, while media developers should ensure that puzzle components align with learning objectives, content complexity, and collaborative activities. Future studies should also involve diverse research subjects and quasi-experimental designs to compare students using CIZLE with control groups and provide stronger evidence of its effectiveness. Available next action: Create a downloadable DOCX file here in this chat containing the findings and recommendations above

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