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Research Article

The Effect of Media Crossword Puzzles Based on Polya's Problem-Solving on Improving Students' Problem-Solving Skills in the Human Skeletal System Material

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ABSTRACT

Purpose of the study: This study aims to analyze the effect of Polya-based problem-solving Crossword Puzzle media in improving students' problem-solving skills on the Human Skeletal System material.

Methodology: The study uses a quantitative approach with a quasi-experimental method and a pretest-posttest control group design. The research sample consisted of 40 students who were divided into an experimental class and a control class using a total sampling technique. Data collection was conducted using problem-solving ability tests, observations, and questionnaires, while data analysis included normality and homogeneity tests and independent-samples t-tests, all conducted in IBM SPSS Statistics 25.

Main Findings: The research results indicate that the developed media is highly feasible, as validated by experts. The average posttest score for the experimental class was 86.25, higher than that of the control class which was 65.00. The hypothesis test results showed a t-value of 9.920 with Sig. (2-tailed) = 0.000 (<0.05), indicating a significant difference between the two groups. These findings demonstrate that the Polya problem-solving-based Crossword Puzzle media improves students' problem-solving skills.

Novelty/Originality of this study: The novelty of this study lies in integrating the Polya problem-solving steps into the Crossword Puzzle media, so it not only functions as a concept reinforcement tool but also as a means to develop systematic, analytical, and reflective thinking skills in biology learning.

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1. INTRODUCTION

21st-century education requires students not only to master knowledge concepts but also to have higher-order thinking skills (HOTS), especially the ability to think critically, creatively, collaboratively, communicatively, and solve problems [1], [2]. Problem-solving skills are one of the essential competencies because they allow students to identify problems, analyze information, come up with alternative solutions, and make decisions based on scientific evidence. In the context of learning biology, these skills are really necessary considering the nature of biology material, which requires understanding concepts, connections between

systems, and applying knowledge to explain life phenomena [3], [4]. Therefore, the process of learning biology needs to be designed innovatively so that it not only focuses on mastering the material, but also on developing students' problem-solving skills.

The importance of problem-solving skills also aligns with the goals of national education as mandated in Law Number 20 of 2003 concerning the National Education System, which is to develop students' potential so they become knowledgeable, creative, independent, and responsible individuals [5]. From an Islamic education perspective, the ability to think and solve problems is an implementation of Allah's command to use reason in understanding the signs of His greatness, as mentioned in QS. Az-Zumar verse 9. Therefore, learning should give students the opportunity to construct knowledge through the process of scientific thinking, not just by memorizing concepts. Student-centered learning is expected to create meaningful learning experiences so that the knowledge gained can be applied in everyday life [6].

However, the facts on the ground show that students' problem-solving abilities are still relatively low. This low ability can be seen from the results of the Programme for International Student Assessment (PISA), which indicate that most Indonesian students have not yet reached the minimum competency in science literacy. This situation is also reflected in biology learning at schools, which is still dominated by lecture methods focused on delivering material, causing students to tend to memorize concepts without understanding the connections between them or their application in solving real problems. As a result, students struggle when faced with questions that require analytical, reasoning, and problem-solving skills.

This issue was also found at MA Al-Wardah Medan based on observations and interviews with the biology teacher. Learning on the topic of the human skeletal system showed that students' learning completeness was still around 40–60%, which is lower than the Learning Achievement Criteria of 80%. In addition, students had trouble understanding scientific terms, distinguishing the functions of organs in the skeletal system, and connecting concepts to real-life cases. This situation shows that the learning process hasn't fully helped students develop systematic thinking and problem-solving skills on their own, so more interactive, contextual, and student-centered learning innovations are needed.

One alternative that can be applied is the use of Crossword Puzzle learning media combined with a problem-solving approach according to Polya [7]. Crossword Puzzle is an educational tool that presents concepts in the form of a crossword, making learning more engaging, challenging, and at the same time boosting students' motivation. Various studies report that using Crossword Puzzles can improve learning outcomes, concept retention, motivation, and science process skills. However, most previous research has still used Crossword Puzzles mainly as a tool for reinforcing concepts and practicing term recall, so it hasn't fully developed students' problem-solving abilities yet [8]. Therefore, it's necessary to develop media that not only focuses on grasping concepts, but also guides learners through higher-level thinking by following a systematic problem-solving process.

Polya's problem-solving approach offers a thinking framework that consists of four steps: understanding the problem, devising a plan, carrying out the plan, and looking back. These four steps help learners develop analytical, logical, reflective, and systematic thinking skills in solving various problems [9]. Integrating Polya's stages into Crossword Puzzle media allows each clue or question to not only serve as a way to recall concepts, but also as a means for students to analyze cases, connect biological concepts, figure out the right solutions, and reevaluate the answers they get [10]. Thus, learning media no longer just function as visual aids, but become media that can actively develop higher-order thinking skills.

Although various studies have reported that crossword puzzle media can improve learning outcomes, motivation, concept retention, and student engagement in biology learning, its use is still mainly limited to reinforcing concepts and evaluating learning. On the other hand, the Polya problem-solving approach has been shown to enhance critical thinking and problem-solving skills, but it is more commonly applied to math learning than to biology [11], [12]. Besides that, previous studies generally tested the effect of Crossword Puzzles on learning outcomes or learning motivation without integrating Polya's problem-solving steps as a systematic learning strategy [13], [14]. Thus, there is still a research gap, both conceptually and empirically, as there haven't been many studies examining the effectiveness of integrating Crossword Puzzle media with Polya's problem-solving steps in improving students' problem-solving abilities in biology learning, particularly on the Human Skeletal System topic, which has complex characteristics and requires analytical skills regarding the relationships between structure, function, organ mechanisms, and various disorders related to daily life [15], [16].

Based on that gap, this study offers something new by integrating Crossword Puzzle media with Polya's four stages of problem-solving: understanding the problem, devising a plan, carrying out the plan, and looking back at the results. Unlike previous studies that only used Crossword Puzzles as a tool for practicing concepts or enriching material, this study designs each clue, case, and activity in the Crossword Puzzle to be part of a step-by-step problem-solving process. Through this integration, students are not only required to remember biology concepts, but also to analyze contextual problems, come up with a solution strategy, provide answers based on scientific concepts, and reflect on the results they achieve. Therefore, this study is expected to provide a

theoretical contribution in the form of additional empirical evidence regarding the effect of using Crossword Puzzle media on students' problem-solving abilities, as well as to be a more effective alternative for learning biology on the Human Skeletal System material.

2. RESEARCH METHOD

This study uses a quantitative approach with a quasi-experiment method, because the researcher does not fully randomize the subjects in determining the experimental and control groups [17]. The research design used is a Pretest–Posttest Control Group Design, which aims to compare students' problem-solving abilities before and after being given treatment in both groups. This design was chosen because it can more objectively measure changes in students' abilities due to the application of Polya-based problem-solving Crossword Puzzle media through the administration of pretests and posttests [18]. The research design can be stated as follows Table 1.

Table 1. Pretest–Posttest Control Group Research Design

Group	Pretest	Treatment	Posttest
Experimental	O_1	X	O_2
Control	O_1	–	O_2

Description:
O_1 = Pretest measurement before the treatment is given
X = Treatment using the Science Literacy-Based Smart Card Media
O_2 = Posttest measurement after the treatment is given
– = No treatment (conventional learning method)

The research was carried out in May 2026 at MA Al-Wardah Medan with the subject of the Human Skeletal System. The study population consisted of all 40 students in grade XI, divided into two classes. The sampling technique used was total sampling, meaning all members of the population were included in the study since the population was less than 100 students. Thus, class XI MIPA 1 was designated as the experimental class and class XI MIPA 2 as the control class, each consisting of 20 students.

The independent variable in this study is the use of a Crossword Puzzle media based on Polya's problem-solving method, while the dependent variable is the students' problem-solving ability on the Human Skeletal System material. The implementation of the media in the experimental class follows the four stages of problem-solving according to Polya, which are understanding the problem, devising a plan, carrying out the plan, and looking back at the results [19]. These stages are integrated into Crossword Puzzle activities so that students not only remember concepts, but also analyze cases, determine solutions strategies, implement solutions, and reflect on the results they get. Meanwhile, the control class received conventional learning through lectures, Q&A, and assignments without using Polya-based Crossword Puzzle media.

The research instruments include a problem-solving ability test, observation sheets, and a student response questionnaire. The test instrument consists of 20 questions developed based on Polya's problem-solving ability indicators. Before being used, the instruments were validated by media experts, material experts, and evaluation experts, then tested for validity, reliability, difficulty level, and discriminating power. The validity test used the Pearson Product Moment correlation with the formula:

$$r_{\{xy\}} = \backslash frac\{N\sum XY - (\sum X)(\sum Y)\}\left\{\sqrt{\{[N\sum X^{\{2\}} - (\sum X)^{\{2\}}][N\sum Y^{\{2\}} - (\sum Y)^{\{2\}}]\}}\right\} \ldots (1)$$

A test item is considered valid if it meets the following criteria:

$$r_{count} > r_{table} \ldots (2)$$

The reliability test of the instrument uses Cronbach's Alpha coefficient with the equation:

$$\alpha = \left(\frac{k}{k-1}\right)\left(1 - \frac{S\sum S_i^2}{S_t^2}\right) \ldots (3)$$

Description:
(α) = Reliability coefficient
(k) = Number of test items
(ΣS_i^2) = Total variance of each item
(S_t^2) = Total variance of the test scores

An instrument is considered reliable if the Cronbach's Alpha value is ≥ 0.70. Based on the test results, the instrument has a Cronbach's Alpha value of 0.803, so it falls into the very reliable category and is suitable to be used as a tool to measure students' problem-solving abilities. Data were collected through tests, observations, and questionnaires. The tests were given as a pretest before the treatment and a posttest after the treatment to measure the improvement in students' problem-solving skills. Observations were used to watch the implementation of learning and students' activities during the learning process, while questionnaires were used to get students' responses to the use of problem-solving-based Crossword Puzzle media using Polya's method [20].

Data analysis was done using IBM SPSS Statistics version 25. The analysis started with descriptive statistics to get the mean, standard deviation, minimum, and maximum values. Next, a normality test was conducted using Shapiro–Wilk because the number of samples was less than 50 students. Data is considered normally distributed if it meets the criteria: Sig.>0,05.

Next, a homogeneity test was carried out using Levene's Test with the criteria: which shows that the variances of the two groups are homogeneous. *Sig.>0,05.* After meeting the prerequisite tests, hypothesis testing was carried out using an Independent Sample t-test to find out the difference in problem-solving abilities between the experimental class and the control class. The test statistic used is:

$$t = \frac{\{X\}_1 - \{X\}_2}{\sqrt{\left\{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right\}}} \quad \ldots (4)$$

Description:
(\bar{X}_1) = Mean score of the experimental class
(\bar{X}_2) = Mean score of the control class
(S_1^2) = Variance of the experimental class
(S_2^2) = Variance of the control class
(n_1) = Number of samples in the experimental class
(n_2) = Number of samples in the control class

The decision on hypothesis testing is based on a 5% significance level (α = 0.05), meaning that H_0 is rejected and H_1 is accepted if the Sig. (2-tailed) value is < 0.05, indicating that Polya problem-solving-based Crossword Puzzle media has a significant impact on students' problem-solving skills in the topic of the Human Skeletal System.

3. RESULTS AND DISCUSSION

The results of this study are presented systematically based on the stages of the research, which include media and instrument validation, testing instrument quality, analyzing students' problem-solving abilities, and testing hypotheses. The presentation of the results aims to provide an overview of the effectiveness of problem-solving-based Crossword Puzzle media in improving students' problem-solving skills on the Human Skeletal System material at MA Al-Wardah Medan.

Validation of Research Media and Instruments

Before being implemented in the learning process, the problem-solving Polya-based Crossword Puzzle media, test instruments, and learning modules first go through a validation stage by media experts, material experts, and instrument experts to ensure the feasibility of the developed product. Validation is carried out on aspects of content, presentation, language, and the suitability of the media with the learning objectives as well as the problem-solving skills being measured. The validation results are presented in Table 3.

Table 3. Results of Media, Instrument, and Learning Module Validation

Validator	Percentage	Category
Media Expert Validation	90%	Very Valid
Test Instrument Expert Validation	85%	Very Valid
Learning Module Validation	90%	Very Valid

Based on the validation results in Table 3, the Polya problem-solving-based Crossword Puzzle media scored a feasibility percentage of 90% with a very valid category. The test instrument validation results obtained a percentage of 85%, while the learning module got 90%, both also in the very valid category. These percentages show that the media, research instruments, and learning tools have met the feasibility aspects in terms of content, appearance, language, and alignment with learning objectives.

Even so, the validator gave some feedback for product improvement, such as refining the wording in several question instructions, improving the media layout, and adjusting illustrations to better represent the human skeletal system material. All of these suggestions were accommodated through a revision process before the media and instruments were implemented in learning activities. Overall, the validation results showed that the Polya problem-solving-based Crossword Puzzle media, research instruments, and learning modules met the

very valid criteria, making them suitable to be used as learning tools for measuring and enhancing students' problem-solving skills on the Human Skeletal System material.

Instrument Validity Test Results

Validity testing was conducted using the Pearson Product-Moment correlation with the help of IBM SPSS Statistics 25 at a 5% significance level, involving 32 student respondents in the trial. Based on the analysis results, the r-table value obtained was 0.349. All the test items had r-count values higher than the r-table, ranging from 0.355 to 0.737. Out of the 20 items tested, all were declared valid, with some items categorized as valid and others as highly valid. These results indicate that each test item was able to measure problem-solving ability indicators according to the research objectives, so all instruments are suitable for use in the data collection phase. The complete validity test results are presented in Table 4.

Table 4. Results of the Item Validity Test

Item	Calculated r (r-value)	Critical r (r-table)	Category
Item 01	.541**	0.349	Very Valid
Item 02	.418*	0.349	Valid
Item 03	.539**	0.349	Very Valid
Item 04	.407*	0.349	Valid
Item 05	.551**	0.349	Very Valid
Item 06	.548**	0.349	Very Valid
Item 07	.385*	0.349	Valid
Item 08	.504**	0.349	Very Valid
Item 09	.479**	0.349	Very Valid
Item 10	.409*	0.349	Valid
Item 11	.478**	0.349	Very Valid
Item 12	.474**	0.349	Very Valid
Item 13	.385*	0.349	Valid
Item 14	.355*	0.349	Valid
Item 15	.387*	0.349	Valid
Item 16	.355*	0.349	Valid
Item 17	.434*	0.349	Valid
Item 18	.370*	0.349	Valid
Item 19	.424*	0.349	Valid
Item 20	.737**	0.349	Very Valid

After all the test items were declared valid, a reliability test was then conducted using the Cronbach's Alpha method. The analysis results showed that the instrument obtained a Cronbach's Alpha value of 0.803. This value falls into the very reliable category, indicating that the instrument has a high level of internal consistency. Thus, the instrument can provide stable and consistent measurement results when used under relatively similar conditions. The reliability test results are presented in Table 5.

Table 5. Item Reliability Test Results

Cronbach's Alpha	Number of Items
0.803	20

Difficulty Level Test Results

The difficulty level test was conducted to determine how challenging each question used in the study was. Based on the analysis, most of the questions fall into the medium category, with 18 questions, while 2 questions are in the easy category, and there are no questions classified as difficult. This composition shows that the instrument has a proportional difficulty level, so it can measure students' abilities across different levels of material mastery without being dominated by questions that are too easy or too hard. The results of the difficulty level test are presented in Table 6.

Table 6. Results of the Item Difficulty Level Test

Difficulty Index	Item Numbers	Category
0.00–0.30	–	Difficult
0.31–0.70	1, 2, 3, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20	Moderate
0.71–1.00	4, 11	Easy

Discriminative Test Results

The discrimination power test was carried out to determine each question item's ability to distinguish students with high and low abilities. The analysis results showed that 14 questions were in the fair category, while 6 questions were in the good category. In addition, no questions were found to be in the poor category or had negative discrimination power. These findings indicate that all question items are adequately capable of differentiating students' ability levels, so they are suitable to be used as research instruments. The results of the discrimination power test are presented in Table 7.

Table 7. Results of the Item Discrimination Index Test

Discrimination Index	Item Numbers	Category
0.00–0.19	–	Poor Items
0.20–0.39	2, 4, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19	Fair Items
0.40–0.69	1, 3, 5, 6, 8, 20	Good Items
0.70–1.00	–	Excellent Items
Negative	–	Poor Items (Should Be Discarded)

Overall, the results of the instrument quality testing show that the research instrument has met all the measurement requirements, including validity, reliability, difficulty level, and discrimination power. Therefore, the instrument is declared suitable for measuring students' problem-solving abilities on the Skeletal System material in this study.

Problem-Solving Ability Results in the Experimental Class

The problem-solving skills of students in the experimental class were analyzed based on the results of the pretest and posttest after using the Polya-based crossword puzzle problem-solving media. Descriptive analysis was done to see changes in the average scores, standard deviation, minimum scores, and maximum scores of the students. The results of the descriptive statistical analysis are presented in Table 8.

Table 8. Descriptive Statistics of the Experimental Class

Description	Pre-Test	Post-Test
Mean	48.75	86.25
Standard Deviation	8.410	6.463
Minimum Score	35	75
Maximum Score	65	100

Based on the analysis results presented in Table 8, the average pretest score of students in the experimental class was 48.75, with a standard deviation of 8.410, a minimum score of 35, and a maximum score of 65. These results indicate that students' problem-solving abilities before receiving the treatment were still in the low category. After implementing learning using the Polya problem-solving-based Crossword Puzzle media, the average posttest score increased to 86.25, with a standard deviation of 6.463, a minimum score of 75, and a maximum score of 100. The increase in the average score by 37.50 points indicates an improvement in students' problem-solving abilities after participating in the learning process.

In addition to the increase in the average score, the standard deviation decreased from 8.410 in the pretest to 6.463 in the posttest. This decrease indicates that the variation in students' abilities became smaller after the learning process, meaning that students' problem-solving abilities not only improved but also became more evenly distributed. All students obtained posttest scores above 75, indicating that most students had achieved a good level of mastery of the learning material after participating in learning activities using the developed media.

Problem-Solving Ability Results in the Control Class

The problem-solving abilities of students in the control class were analyzed based on the results of the pretest and posttest after participating in learning using conventional methods. Descriptive analysis was carried out to find out the changes in the average scores, standard deviation, minimum, and maximum values of students before and after the learning process. The results of the descriptive statistics are presented in Table 9.

Table 9. Descriptive Statistics of the Control Class

Description	Pre-Test	Post-Test
Mean	49.00	65.00
Standard Deviation	8.046	7.071
Minimum Score	35	55
Maximum Score	65	80

Based on the analysis in Table 9, the average pretest score was 49.00 with a standard deviation of 8.046, a minimum score of 35, and a maximum score of 65. These results show that students' problem-solving skills before learning were still in the low category. After going through conventional learning, the average posttest score increased to 65.00 with a standard deviation of 7.071, a minimum score of 55, and a maximum score of 80. The average increase of 16.00 points shows that conventional learning still improves students' problem-solving skills, although the improvement is not yet optimal. Besides the increase in the average score, the standard deviation also dropped from 8.046 to 7.071, which shows that the students' abilities became more evenly distributed after the learning process. However, the posttest score range is still in the medium category with a maximum score of 80, so the students' problem-solving skills have not yet reached the same level as those in the experimental class.

Comparison of Problem-Solving Ability between the Experimental Class and the Control Class

The comparison of students' problem-solving abilities was carried out based on the posttest results in the experimental class and the control class after each group received different teaching treatments. This analysis aims to give an idea of the differences in problem-solving skills between students who learned using a Polya-based problem-solving Crossword Puzzle and students who underwent conventional learning. The results of the posttest score distribution comparison are shown in Figure 1.

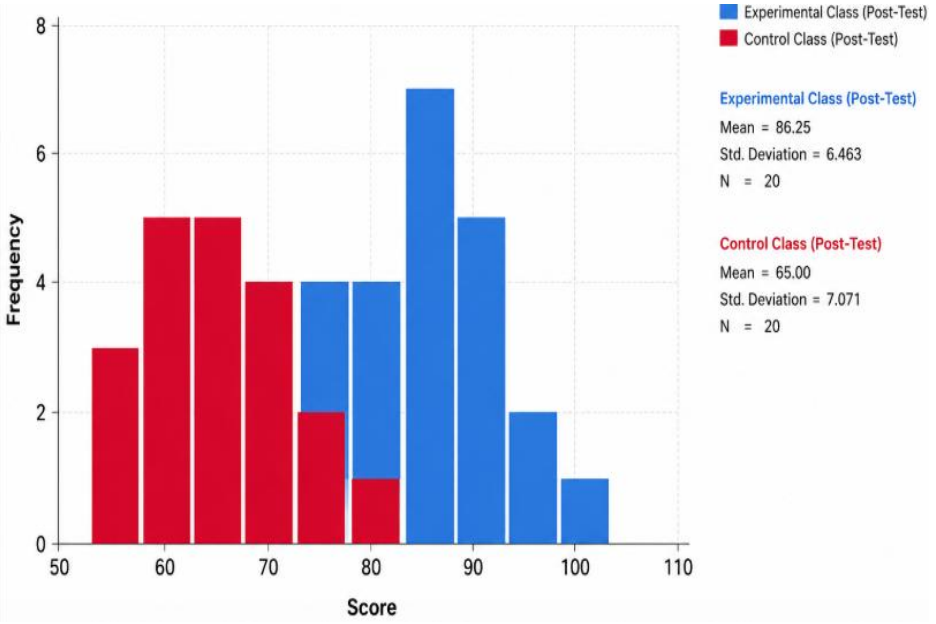

Figure 1. Comparison of Post-Test Score Distribution in the Experimental and Control Classes

Based on the analysis results, the experimental class got an average posttest score of 86.25, while the control class got an average of 65.00. So, there's an average difference of 21.25 points between the two groups. This difference shows that students who learned using Polya problem-solving-based Crossword Puzzle media scored higher compared to students who learned through conventional methods.

The score distribution in Figure 3 shows that most students in the experimental class scored between 80 and 90, and some even reached 100, indicating that their problem-solving ability is in the high category. On the other hand, the control class scores are mostly in the 60–70 range, with a maximum score of 80, showing that their problem-solving ability is still in the medium category. This difference in distribution patterns suggests that the learning outcomes of students in the experimental class are better and more evenly spread than those in the control class. Overall, the comparison results between the two groups show that using problem-solving Polya-based Crossword Puzzle media leads to higher problem-solving skills compared to conventional learning. These findings serve as a basis for conducting statistical hypothesis testing to determine the significance of the differences in problem-solving abilities between the experimental and control classes.

Prerequisite Test Results for Analysis

Before conducting hypothesis testing, prerequisite analysis tests were first carried out, including normality and homogeneity tests. These prerequisite tests aim to ensure that the research data meet the assumptions of parametric statistics, making them suitable for analysis using an independent sample t-test. The results of the prerequisite analysis tests are presented in Table 10 and Table 11.

Normality Test Results

The normality test was carried out using Shapiro–Wilk because the number of samples in each group was less than 50 students. The test was conducted on pretest and posttest data in both the experimental and control classes. The results of the normality test are presented in Table 10.

Table 10. Results of the Normality Test for Problem-Solving Skills

Description	Shapiro–Wilk Statistic	df	Sig.
Experimental Class Pre-Test (Crossword Puzzle)	.961	20	.559
Experimental Class Post-Test (Crossword Puzzle)	.946	20	.313
Control Class Pre-Test (Conventional)	.958	20	.499
Control Class Post-Test (Conventional)	.938	20	.224

Based on the analysis results in Table 10, the pretest data for the experimental class had a significance value of 0.559, while the control class had 0.499. Next, the posttest data for the experimental class had a significance value of 0.313, whereas the control class had 0.224. All significance values (Sig.) are greater than 0.05, so it can be concluded that both the pretest and posttest data for both groups are normally distributed. Therefore, the research data meets the normality assumption and can proceed to the next stage of analysis using parametric statistical tests.

Homogeneity Test Results

After the data was declared normally distributed, a homogeneity test was then conducted using Levene's Test to find out the similarity of variances between the experimental class and the control class. The results of the homogeneity test are presented in Table 11.

Table 11. Results of the Homogeneity of Variance Test for Problem-Solving Skills

Homogeneity of Variance Test	Levene Statistic	df1	df2	Sig.
Based on Mean	.149	1	38	.702
Based on Median	.297	1	38	.589
Based on Median and with Adjusted df	.297	1	37.939	.589
Based on Trimmed Mean	.204	1	38	.654

The analysis results showed that the significance value based on the Mean was 0.702, while the significance values based on the Median, Median with Adjusted df, and Trimmed Mean were 0.589, 0.589, and 0.654, respectively. All of these significance values are greater than 0.05, so it can be concluded that the variance in problem-solving ability in the experimental class and the control class is homogeneous. Overall, the results of the normality and homogeneity tests indicate that the research data meet all the assumptions required in parametric statistical analysis. Therefore, the data is suitable for hypothesis testing using an independent sample t-test to determine the differences in problem-solving ability between the experimental class and the control class.

Hypothesis Test Results

Hypothesis testing was carried out to find out whether there is a difference in problem-solving abilities between students who learned using the Polya-based problem-solving Crossword Puzzle media and students who followed conventional learning. After the data were confirmed to meet the assumptions of normality and homogeneity, hypothesis testing was done using an independent sample t-test at a 5% significance level (α = 0.05). The results of the hypothesis testing are presented in Table 12.

Table 12. Results of the Independent Samples t-Test

Independent Samples t-Test	Levene's Test for Equality of Variances		t-Test for Equality of Means		
	F	Sig.	t	df	Sig. (2-tailed)
Equal variances assumed	.149	.702	9.920	38	.000
Equal variances not assumed	–	–	9.920	37.697	.000

Based on the analysis results presented in Table 12, the Levene's Test obtained a value of F = 0.149 with a significance value of 0.702 (> 0.05). These results indicate that the variances of the two groups were homogeneous; therefore, the interpretation of the hypothesis test results was based on the Equal Variances Assumed row. The results of the independent sample t-test showed a value of t = 9.920 with degrees of freedom

(df) = 38 and a Sig. (2-tailed) value of 0.000, which was lower than the significance level of 0.05. Furthermore, the Mean Difference value was 21.250, indicating that the average problem-solving ability of students in the experimental class was 21.25 points higher than that of students in the control class. The 95% Confidence Interval ranged from 16.913 to 25.587, indicating that the difference in the average scores between the two groups was positive and consistent.

Based on these results, H_0 was rejected and H_1 was accepted, indicating that there was a significant difference between the problem-solving abilities of students who learned using the Polya problem-solving-based Crossword Puzzle media and students who learned using conventional learning methods. These findings demonstrate that the implementation of the Polya problem-solving-based Crossword Puzzle media had a significant effect on improving students' problem-solving abilities on the Human Skeletal System topic at MA Al-Wardah Medan.

The results of the study show that the implementation of the Polya problem-solving-based Crossword Puzzle media significantly influenced students' problem-solving abilities in the Human Skeletal System material at MA Al-Wardah Medan. This finding was supported by the results of the independent sample t-test, which showed a value of t = 9.920 with Sig. (2-tailed) = 0.000 (<0.05), indicating a significant difference between the experimental class and the control class. The average posttest score of the experimental class reached 86.25, while the control class obtained only 65.00, with an average difference of 21.25 points. In addition, the standard deviation of the experimental class decreased from 8.410 in the pretest to 6.463 in the posttest, indicating that the improvement in learning outcomes did not only occur among certain students but was distributed more evenly across the class. These results indicate that the use of Crossword Puzzle media integrated with Polya's problem-solving steps was able to create a more effective learning process compared to conventional learning methods.

The findings support the theory [7], [21] which states that problem-solving skills develop through four systematic stages, namely understanding the problem, devising a plan, carrying out the plan, and looking back. These four stages become the foundation in learning that guides students to understand the issues, identify important information, design a solution strategy, execute the chosen strategy, and then reflect on the obtained solution. In this study, every activity in the Crossword Puzzle media is designed to follow this thinking flow so that students not only search for answers but also build scientific reasoning before determining the correct terms or concepts in the crossword. Thus, the media not only functions as an evaluation tool but also serves as a means to facilitate higher-order thinking skills.

From the perspective of constructivist theory, this research shows that students get the chance to actively construct knowledge through meaningful learning experiences. [22], [23] explaining that knowledge is built through the processes of assimilation and accommodation when learners interact with the learning environment. This view is reinforced by [24], [25] which emphasizes the importance of social interaction, discussion, and collaboration in developing students' cognitive abilities. During learning using Polya-based Crossword Puzzles, students actively discuss, exchange ideas, and engage in scientific arguments to determine the correct answers. These activities allow for scaffolding to form between students as well as between teachers and students, so that the concepts of the human skeletal system are understood more deeply. This explains why the improvement in problem-solving skills in the experimental class is much higher compared to the control class, which still uses conventional learning methods.

Empirically, the results of this study align with various recent studies on the effectiveness of game-based learning media. Research [26], [27], Through meta-analysis, it shows that both digital and non-digital game-based learning have a positive effect on cognitive learning outcomes compared to traditional learning. Next, [28], [29] explaining that educational games can boost intrinsic motivation, student engagement, and concept retention because students learn through fun challenges. In the context of this study, Crossword Puzzles create a learning environment that is both competitive and collaborative, encouraging students to keep exploring biology concepts until they find the correct answers.

The research findings also support the results of the study [30], [31] which reports that game-based interactive learning media significantly improve critical thinking skills and biology learning outcomes. According to them, the characteristics of games that include elements of challenge, immediate feedback, and problem-solving can boost students' mental activity during the learning process. A similar thing is seen in this study, where students not only memorize the anatomical terms of the human skeletal system but also connect organ functions, working mechanisms, and interrelated concepts before filling in answers on the Crossword Puzzle. This process shows that learning media serve as a tool to build conceptual understanding while also developing scientific thinking skills.

Furthermore, this research reinforces the findings [32], [33] which states that interactive media can improve learning retention through active student involvement. In this study, there was a noticeable shift in score distribution from the 40–60 range in the pretest to 80–100 in the posttest for the experimental class. All students even scored above 75 after participating in learning using the Polya-based Crossword Puzzle. This shift in distribution shows that the improvement was not only in the average score but also in equal mastery of concepts.

In other words, the media developed successfully reduced the gap in abilities between students by providing the same learning opportunities through exploratory and collaborative activities.

If examined based on the Cognitive Load Theory proposed by [34], [35], The use of Crossword Puzzles can also help optimize the cognitive load of students. Presenting information in the form of keywords, contextual clues, and answer-finding activities helps students process information gradually, so their working memory isn't overloaded. Presenting material in an engaging way makes it easier for students to integrate new knowledge with the prior knowledge they already have. Because of this, learning becomes more effective compared to lecture methods, which often lead students to receive information passively.

The results of this study also show that the success of learning is not only influenced by the media, but also by the learning approach used. The integration of Crossword Puzzle with Polya's problem-solving model creates a synergy between playing activities and the scientific thinking process. According to [36], [37], Problem-based learning gives students the chance to develop their skills in analysis, reasoning, decision-making, and reflection by solving real problems. So, when game media is combined with a problem-solving approach, students not only get a fun learning experience but also grow their critical, creative, and reflective thinking skills, which are key competencies in 21st-century learning [38]-[43].

The difference in learning outcomes between the experimental class and the control class also shows that conventional learning tends to remain teacher-centered, resulting in limited opportunities for students to explore concepts independently. In contrast, learning using the Polya problem-solving-based Crossword Puzzle media places students at the center of the learning process (student-centered learning). This approach is in line with the Merdeka Curriculum policy, which emphasizes the importance of active, collaborative, contextual learning, and learning oriented toward the development of higher-order thinking skills [44]-[48]. Therefore, the developed media is not only relevant to modern learning theories but also supports the implementation of national education policies in improving the quality of science learning [49]-[51].

This study strengthen previous research findings stating that game-based learning media can improve students' learning motivation, learning outcomes, critical thinking skills, and problem-solving abilities. However, this study provides a more specific contribution by integrating the Crossword Puzzle media with Polya's problem-solving stages, a combination that is still relatively rarely applied in Biology learning, particularly in the Human Skeletal System topic at the Madrasah Aliyah level. This integration was proven to not only improve learning outcomes statistically but also develop students' systematic, logical, and reflective thinking abilities. Thus, the Polya problem-solving-based Crossword Puzzle media can be recommended as an effective learning innovation to support the development of problem-solving skills in Biology learning.

4. CONCLUSION

This study shows that using Crossword Puzzle media based on Polya problem-solving significantly affects students' problem-solving abilities on the Human Skeletal System material at MA Al-Wardah Medan. This is proven by the Independent Sample t-test results, which showed a t-value of 9.920 with Sig. (2-tailed) = 0.000 (<0.05), indicating that the problem-solving ability of students in the experimental class is significantly higher than that in the control class. These findings suggest that integrating Crossword Puzzle media with the Polya problem-solving steps can create more active, meaningful, and student-centered learning, making it an innovative alternative to support the implementation of the Merdeka Curriculum and the development of higher-order thinking skills. Even so, this study is still limited to a relatively small sample size, a single research location, and only covers Human Skeletal System material, so the generalization of the findings is still limited. Therefore, future research is recommended to involve a larger and more diverse sample, test the application of media on different materials or education levels, and examine its impact on other variables like critical thinking, creativity, learning motivation, science literacy, and learning retention, including developing the media in digital form to be more adaptive to the development of learning technology.

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AUTHOR CONTRIBUTIONS

Conceptualization, Methodology, Formal analysis, WRR; Data curation, R; Investigation, WRR & R; Writing – original draft preparation, WRR & R; Writing – review and editing, WRR & R; Validation, WRR & R. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

INFORMED CONSENT STATEMENT

Prior to participation, each subject was provided with a detailed explanation of the study's objectives, procedures, potential risks, and benefits. All participants voluntarily agreed to participate and signed a written informed consent form. All images in this article have been authorized and are the property of the authors.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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