Journal of Academic Biology and Biology Education
Vol. 2, No. 2, December 2025, pp. 198~207
ISSN: 3062-9705, DOI: 10.37251/jouabe.v2i2.3196

The Advantages of the Jigsaw Model in Protista Learning: A Comparative Study of Conventional Learning

Siti Farihah[1], Novita Vandrianur[2], Fitri Gumulya[3]
[1]Department of Biology Education, Syarif Hidayatullah State Islamic University Jakarta, Banten, Indonesia
[2,3]Madrasah Aliyah Nihayatul Amal Rawamerta, West Java, Indonesia

Article Info

Article history:

Received Oct 12, 2025
Revised Nov 13, 2025
Accepted Nov 28, 2025
Online First Dec 25, 2025

Keywords:

Biology Education
Conventional Learning
Jigsaw Cooperative Learning
Learning Outcomes
Protista Concept

ABSTRACT

Purpose of the study: This study aims to determine the differences in the improvement of student learning outcomes on the Protista concept between students taught using the Jigsaw type cooperative learning model and students taught using conventional learning at the Madrasah Aliyah level.

Methodology: This study used a quasi-experimental method with a Pre-Test–Post-Test Control Group Design. The sample was determined through purposive sampling and simple random sampling. The research instruments consisted of a 30-item multiple-choice test, an affective observation sheet, N-gain analysis, the Liliefors test, the Fisher exact test, and the t-test. Data processing was carried out using descriptive and inferential statistical analysis.

Main Findings: Jigsaw cooperative learning showed higher learning outcomes compared to conventional learning. The average N-gain for the experimental class was 0.33, while the control class was 0.18. The t-test results showed a significant difference (t count 3.75 > t table 1.99). The Jigsaw model also increased student participation, cooperation, responsibility, and engagement in understanding the concept of Protista.

Novelty/Originality of this study: The novelty of this research lies in its comparative analysis of the effectiveness of the Jigsaw cooperative learning model on Protista material, which has rarely been specifically studied. This research provides new empirical evidence regarding the influence of Jigsaw on improving students' cognitive and affective learning outcomes, while also expanding the reference list for student-centered biology learning strategies.

Corresponding Author:
Siti Farihah
Department of Biology Education, Syarif Hidayatullah State Islamic University Jakarta, Jl. Ir. H. Djuanda No. 95, Cemp. Putih, Ciputat, South Tangerang City, Banten 15412, Indonesia.
Email: strihafarihah90@gmail.com

1. INTRODUCTION

Education is a crucial aspect in developing quality human resources. The learning process in schools plays a strategic role in developing students' critical, creative, and analytical thinking skills [1], [2]. In biology, students are required not only to memorize concepts but also to deeply understand the interrelationships between them [3], [4]. This understanding is crucial because biology studies various complex and interconnected life phenomena. Therefore, effective learning strategies are necessary to optimally achieve learning objectives [5], [6].

One indicator of the success of the learning process is student learning outcomes. Learning outcomes reflect students' mastery of the material they have learned through changes in cognitive, affective, and psychomotor aspects [7], [8]. However, in practice, many student learning outcomes still fall short of expectations, particularly in biology [9], [10]. Poor learning outcomes are often influenced by the use of less varied and teacher-centered learning methods [11], [12]. This leads to students being passive and less actively involved in the learning process.

The concept of protists is one of the biology topics taught at the high school level and is quite complex [13], [14]. This material covers the classification, characteristics, body structure, and role of protists in life, requiring strong analytical skills and conceptual understanding. Many students struggle to grasp the concept of protists because the material is abstract and contains a lot of scientific terminology [15], [16]. This difficulty can impact learning outcomes if not supported by appropriate learning strategies. Therefore, teachers need to implement learning models that can help students understand the material more deeply [17], [18].

One learning model that can be implemented to improve student learning outcomes is Jigsaw cooperative learning [19], [20]. This learning model emphasizes collaboration among students in small, heterogeneous groups to exchange information and share responsibility for understanding the material [21], [22]. In its implementation, each student assumes the role of "expert" on a specific subtopic, which must then be explained back to the members of their original group. This process encourages students to actively discuss, communicate, and build understanding collaboratively. Thus, Jigsaw cooperative learning has the potential to increase student engagement in the learning process [23], [24].

On the other hand, conventional learning is still widely used in biology learning in schools. This model is generally dominated by lectures, teacher explanations, and student note-taking [25], [26]. While effective for conveying information quickly, conventional learning often lacks the space for students to explore knowledge independently [27], [28]. As a result, students tend to passively absorb information without engaging in in-depth knowledge construction. This can contribute to low learning outcomes, particularly in topics that require conceptual understanding, such as protists [16], [29].

Various previous studies have shown that Jigsaw cooperative learning can improve learning outcomes in several biology topics [30], [31]. However, most of these studies have focused on ecosystems, organ systems, or genetics, while studies on the concept of protists are relatively limited. Furthermore, there has been little research specifically comparing the improvement in learning outcomes between Jigsaw cooperative learning and conventional learning on the concept of protists [32], [33]. This situation indicates a research gap that requires further study. The novelty of this study lies in its focus on analyzing differences in learning outcomes on the concept of protists through a comparison of two different learning approaches.

The urgency of this research is based on the importance of finding effective learning strategies to improve students' understanding of protists. Given that this material is often considered difficult by students, learning innovations are needed that can significantly increase student engagement and learning outcomes. This research is expected to provide empirical support for biology teachers in selecting appropriate learning models for classroom implementation. Furthermore, the results can serve as a reference for developing more innovative and student-centered biology learning. Based on the description, the main objective of this study is to determine the differences in learning outcomes between students taught through Jigsaw type cooperative learning and conventional learning on the concept of protists.

2. RESEARCH METHOD

2.1. Research Methods and Design

This study employed a quasi-experimental method. This method was chosen because it is quite difficult to obtain a truly ideal control group that meets the research needs. Quasi-experiments allow researchers to still test the effects of a treatment without fully randomizing the subjects. The research design used was a Pre-Test–Post-Test Control Group Design [34], [35]. In this design, the study involved two groups: an experimental group and a control group. The experimental group was given treatment in the form of the Jigsaw cooperative learning model, while the control group was given learning using a conventional model. Furthermore, the learning outcomes of the two groups were analyzed and compared to determine the effects of the treatment. The experimental design in this study was structured in Table 1.

Table 1. Research Design

Group	Pretest	Treatment	Posttest
Experimental	O_1	X1	O_2
Control	O_3	X2	O_4

Based on the research design above, both groups were given a pretest with the same questions (the concept of Protista). After being given different treatments, both groups were given the same test as a final test (posttest). Improvements in test results from each class were compared, as were improvements in test results between the experimental and control groups. Non-tests were administered during the learning process in each class using observation sheets.

2.2. Population and Sample

Population is the entire subject targeted in a study. The target population in this study was all students of Madrasah Aliyah Nihayatul Amal Rawamerta. The accessible population in this study was all grade X students at the school, who were the focus of the study in accordance with the data collection needs. The sampling technique in this study used purposive sampling, namely the selection of samples based on certain predetermined considerations, in this case referring to the subject teacher's policy [36], [37]. The research sample was taken from two classes, namely class X-1 and X-2. Next, simple random sampling was carried out to determine the experimental class and the control class. Based on the randomization results, class X-1 with 49 students was designated as the experimental class, while class X-2 with 46 students was designated as the control class.

2.3. Research Instruments

The instruments used in this study consisted of test and non-test items. In both the experimental and control classes, the test items were written multiple-choice questions with five answer choices, while the non-test items were observation sheets. Both types of instruments were used to obtain data related to cognitive learning outcomes and student attitude development during the learning process [29], [38]. The Protista concept mastery test was used to measure changes in students' understanding before and after participating in the Jigsaw cooperative learning model in the experimental class. Furthermore, this instrument was also used to measure changes in concept mastery in students in the control class who underwent conventional learning.

The cognitive aspects measured in this test included domains C1 (remembering), C2 (understanding), C3 (applying), and C4 (analyzing). The pretest and posttest consisted of 30 multiple-choice questions with five answer choices. Each correct answer was given a score of 1, while each incorrect answer was given a score of 0. Assessment of the attitude aspect in this study was conducted through the use of observation sheets. This observation instrument was used to monitor and assess student character throughout the learning process. Several attitude indicators observed included cooperation, responsibility, discipline, and self-confidence. Observations were conducted systematically to obtain a picture of student attitude development during the implementation of the learning model. The instrument grid on the observation sheet was compiled based on these attitude indicators to serve as a guideline for the assessment. The composition of the research instruments used in this study is shown in Table 2.

Table 2. Observation Sheet Grid for Measuring Student Character in the Learning Process

Assessed Character	Indicator
Teamwork	Exchanging knowledge and sharing
	Good cooperation
	Participating in carrying out assignments
Responsibility	Listening to explanations and completing assignments
	Being active and calm in carrying out tasks
Discipline	Complying with rules
	Being orderly during learning
Self-Confidence	Being able to manage oneself and communicate in various situations
	Having sufficient intelligence
	Being calm when taking quizzes

2.4. Data Processing Techniques

After all the research data was collected, the next step was to systematically process and analyze the data. Data analysis techniques in this study included cognitive and affective data processing. Data processing was carried out to obtain a clear picture of the effect of the Jigsaw cooperative learning model on student learning outcomes in the Protista concept. Cognitive data processing began by calculating raw scores from students' pretest and posttest responses in both the experimental and control classes [39], [40]. The obtained data were then organized into a frequency distribution to facilitate statistical analysis. Descriptive statistics were then calculated, including the mean, median, and mode, to describe the characteristics of the data. Furthermore, a normalized gain (N-gain) calculation was performed to determine the level of improvement in student learning outcomes after participating in the learning process. The N-gain value was obtained from the difference between the posttest and pretest scores compared to the maximum possible score.

Before testing the hypotheses, prerequisite analysis tests were conducted, including normality and homogeneity tests. The Liliefors test was used to determine whether the data were normally distributed. Data were considered normally distributed if the calculated L value was less than or equal to L table at a predetermined significance level [41], [42]. After the data met the normality requirements, a homogeneity test was conducted using Fisher's exact test to determine the equality of variance between the experimental and control classes. Data were considered homogeneous if the calculated F value was less than the F table. After the data were declared normal and homogeneous, the next step was to conduct a hypothesis test using a t-test. This test aimed to determine whether there were differences in biology learning outcomes between students taught using the Jigsaw cooperative learning model and students taught through conventional learning on the concept of Protista. Decision-making was carried out by comparing the calculated t value with the t table at a certain level of significance. If the calculated t value was greater than the t table, the alternative hypothesis was accepted; if the calculated t value was less than the t table, the null hypothesis was accepted.

In addition to testing the final hypothesis, statistical analysis was also conducted to determine differences in learning outcomes between the pretest and posttest in each group. This analysis aimed to determine the extent of improvement in student learning outcomes after being given the learning treatment. Thus, the results of the analysis could provide a clearer picture of the effectiveness of the applied learning model. Affective data processing was carried out based on observations of student behavior during the learning process [43], [44]. Data were obtained by counting the number of checkmarks on each observed attitude indicator, such as cooperation, responsibility, discipline, and self-confidence. Each indicator was scored according to the level of behavior demonstrated by the student, ranging from the lowest to the highest score. The scores obtained were then calculated as a percentage by comparing the total score obtained to the maximum score. The percentage results were then interpreted into specific assessment categories: very poor, poor, fair, good, and very good. This interpretation was used to provide an overview of the development of student attitudes during the learning process using the model applied in the study.

3. RESULTS AND DISCUSSION

The research results described are in the form of pretest, posttest and N-gain values from the experimental class and control class.

3.1. Pretest Data for Experimental and Control Classes

Based on the pretest results of the experimental class using jigsaw type cooperative learning and the control class using conventional learning, the data obtained are in Table 3.

Table 3. Description of Pretest Data for Experimental Class and Control Class

Description	Experiment	Control
Minimum Value	10	10
Maximum Value	57	40
Range	47	30
Mean	26.73	24.28
Median	26.81	22.94
Mode	25.12	21.75
Standard Deviation	10.30	8.02

Based on Table 3, it is known that the average pretest score in the experimental class was 26.73. The average pretest in this class is included in the failing category. Most students obtained biology scores between 24–30, namely 18 students or 36.77%. The highest score was between 52–58, namely 2 students or 4.08%, while the lowest score was between 10–16, namely 1 student or 2.04%. Meanwhile, the average pretest score in the control class was 24.28. The average pretest in this class was included in the failing category. Most students obtained biology scores between 20–24, namely 16 students or 34.78%. The highest score was between 40–44, namely 1 student or 2.17%, while the lowest score was between 10–14, namely 5 students or 10.87%.

3.2. Posttest Data for Experimental and Control Classes

Based on the posttest results of the experimental class using jigsaw type cooperative learning and the control class using conventional learning, the data obtained are in Table 4.

Table 4. Description of Posttest Data for Experimental Class and Control Class

Description	Experiment	Control
Minimum Value	27	10
Maximum Value	80	63
Range	53	53
Mean	53.03	34.33

Median	50.83	32.88
Mode	46.86	29.50
Standard Deviation	14.37	12.27

Based on Table 4, it is known that the average posttest score in the experimental class was 53.03. The average posttest in this class was included in the less category. Most students obtained biology scores between 43–50, namely 12 students or 24.49%. The highest score was between 75–82, namely 4 students or 8.16%, while the lowest score was between 27–34, namely 6 students or 12.24%. Meanwhile, the average posttest score in the control class was 34.33. The average pretest in this class was included in the fail category. Most students obtained biology scores between 26–33, namely 13 students or 28.26%. The highest score was between 58–65, namely 2 students or 4.35%, while the lowest score was between 10–17, namely 2 students or 4.35%.

3.3. N-gain Value Data for Learning Outcomes of the Experimental and Control Classes

The N-gain test was conducted to measure improvements in learning outcomes after teacher instruction. Based on the calculation results, the N-gain value is obtained as shown in table 5.

Table 5. N-gain Value of Learning Outcomes of Experimental Class and Control Class

Description	Experiment	Control
N	49	46
Low Criteria	49%	83%
Medium Criteria	47%	17%
High Criteria	4%	0%
Average	0.33	0.18

Based on Table 5, the N-gain calculation results are significantly different between the experimental and control classes. This is indicated by the average N-gain of the experimental class, which approaches the high criterion.

3.4. Normality of Pretest of Experimental Class and Control Class

The results of the pretest normality test in the experimental class and control class are shown in Table 6.

Table 6. Results of the Pretest Normality Test for the Experimental and Control Classes

Class	N	.α	L_0 (L_{count})	L_{tabel}	Conclusion
Experiment	49	0.05	0.1216	0.1265	Normal
Control	48	0.05	0.1135	0.1306	Normal

Based on Table 6, the Lcount of the experimental class was 0.1216 and the Lcount of the control class was 0.1135. The experimental class with a sample size of 49, obtained an Ltable at a significance level of α = 0.05 of 0.1265. The control class with a sample size of 46, obtained an Ltable at a significance level of α = 0.05 of 0.1306. The comparison between Lcount

3.5. Posttest Normality of Experimental and Control Classes

The results of the posttest normality test in the experimental class and control class can be seen in Table 7.

Table 7. Results of the Posttest Normality Test for the Experimental and Control Classes

Class	N	.α	L_0 (L_{count})	L_{table}	Conclusion
Experiment	49	0.05	0.1122	0.1265	Normal
Control	46	0.05	0.0655	0.1306	Normal

Based on Table 7, the Lcount of the experimental class was 0.1122 and the Lcount of the control class was 0.0655. The experimental class with a sample size of 49, obtained Ltable at a significance level of α = 0.05 of 0.1265. The control class with a sample size of 49, obtained L_{table} at a significance level of α = 0.05 of 0.1306. The comparison between $L_{count} < L_{table}$ for the experimental class (0.1122 <0.1265) and for the control class (0.0655 <0.1306), then H0 is accepted. Thus, it can be concluded that the data is normally distributed.

Table 8. Results of the N-gain Normality Test

Class	N	.α	L_0 (L_{count})	L_{table}	Conclusion
Experiment	49	0.05	0.0702	0.1265	Normal
Control	46	0.05	0.1124	0.1306	Normal

Based on Table 8, the experimental class obtained L_0 (L_{count}) of 0.0702, with a sample size of 49 students with a significance level of 5%, then obtained Ltable of 0.1265. Based on the data above, it can be seen that L0 experimental class < L_{table} (0.0702<0.1265), then the null hypothesis (H_0) is accepted. Thus it can be concluded that the N-gain sample data of the experimental class is normally distributed. Meanwhile, from the calculation of the N-gain normality test of the control class, obtained L_0 (L_{count}) of 0.1124, with a sample size of 46 students with a significance level of 5%, then obtained Ltable of 0.1306. Based on the data above, it can be seen that L0 control class < L_{table} (0.1124<0.1306), then the null hypothesis (H_0) is accepted. Thus it can be concluded that the N-gain sample data of the control class is normally distributed.

3.6. Homogeneity of Pretest of Experimental Class and Control Class

The results of the pretest homogeneity test in the experimental class and control class are presented in table 9.

Table 9. Results of the Pretest Homogeneity Test for the Experimental and Control Classes

Class	N	S^2	F_{count}	F_{table}	Conclusion
Experiment Control	49 48	106.02 66.33	1.60	1.63	Varians homogen

Based on Table 9, the pretest F_{count} for the experimental and control classes was 1.60. At a significance level of $\alpha = 0.05$ with a sample of 49 for the experimental class and 46 for the control class, the Ftable was 1.63. The comparison between $F_{count} < F_{table}$ (1.60 < 1.63), then H_0 is accepted. Thus, it can be concluded that the variance of the two groups is homogeneous.

3.7. Homogeneity of Posttest of Experimental Class and Control Class

The results of the posttest homogeneity test in the experimental class and control class are presented in table 10.

Table 10. Results of the Posttest Homogeneity Test for the Experimental and Control Classes

Class	N	S^2	F_{count}	F_{table}	Conclusion
Experiment Control	49 46	206.46 150.65	1.37	1.63	Varians homogen

Based on Table 10, the posttest F_{count} for the experimental and control classes was 1.37. At a significance level of $\alpha = 0.05$ with a sample of 49 for the experimental class and 46 for the control class, the F_{table} was 1.63. The comparison between $F_{count} < F_{table}$ (1.37 < 1.63), then H_0 is accepted. Thus, it can be concluded that the variance of the two groups is homogeneous.

Table 11. Calculation of N-gain Homogeneity Test

α	Information	F_{count}	F_{table}	Conclusion
0.05	N-gain	1.33	1.63	Homogeneous variance

Based on Table 11, it can be seen that F_{count} N-gain < F_{table} (1.33 < 1.63), so the null hypothesis (H_0) is accepted. Thus, it can be concluded that both N-gain samples are homogeneous.

3.8. Pretest Hypothesis Testing of Experimental and Control Classes

The results of calculating the pretest value using the t-test can be shown in the Table 12.

Table 12. Results of the t-Test of the Pretest Data for the Experimental and Control Classes

Class	N	$\bar{x}$	t_{count}	t_{count}	Conclusion
Experiment Control	49 46	26.73 24.28	1.33	1.99	H_0 accepted

The results of the t-test calculation obtained a tcount of 1.33, and at a significance level of $\alpha = 0.05$, a ttable of 1.99 was obtained. The comparison between tcount < t_{table} (1.33 < 1.99), then H_0 is accepted. Thus, it can be concluded that there is no difference in students' initial knowledge in the experimental class and the control class.

3.9. Posttest Hypothesis Testing of Experimental and Control Classes

The results of calculating the posttest value using the t-test can be shown in the Table 13.

Table 13. Results of the t-Test of the Posttest Data for the Experimental and Control Classes

Class	N	$\bar{x}$	t_{count}	t_{count}	Conclusion
Experiment	49	53.03	6.97	1.99	H_0 rejected
Control	46	34.33			

The results of the t-test calculation obtained t count of 6.97, and at a significance level of $\alpha = 0.05$, t_{table} was obtained at 1.99. The comparison between $t_{count} > t_{table}$ (6.97 > 1.99), then H_0 is rejected, meaning that the average biology learning outcomes of experimental class students are significantly different from the biology learning outcomes of control class students. Thus, it can be concluded that there are differences in learning outcomes between students taught through jigsaw type cooperative learning and conventional learning on the concept of protists.

Table 14. Results of the t-test of N-gain data

Class	Amount	Dk	t_{count}	t_{table}	Conclusion
Experiment	$\bar{x}_1 = 0.33$ $SD_1 = 13.86$	93	3.75	1.99	H_0 ditolak
Control	$\bar{x}_2 = 0.18$ $SD_2 = 12.75$				

The results of the t-test calculation obtained $t_{count} > t_{table}$ (3.75> 1.99) to compare the average N-gain of the two groups. Therefore, the alternative hypothesis (H_a) is accepted and the null hypothesis (H_0) is rejected. Thus, it can be concluded that there is a difference in the increase in learning outcomes between students taught through jigsaw cooperative learning and conventional learning on the concept of protists. while the results of the calculation of the average N-gain of student learning outcomes between the two groups show that the biology learning outcomes of students taught through jigsaw cooperative learning are better than the biology learning outcomes of students taught through conventional learning, namely the average (mean) increase in learning outcomes of students in the jigsaw group is 0.33 and the average (mean) increase in learning outcomes of students in the conventional group is 0.18.

The results of this study indicate that the application of the Jigsaw cooperative learning model provides a more meaningful learning experience than conventional learning in the Protista topic. The advantage of the Jigsaw model lies not only in the delivery of the material, but also in the interaction process between students, which encourages active knowledge construction. In Jigsaw learning, each student assumes the responsibility of being an "expert" on a specific subtopic, encouraging them to deeply understand the material before explaining it to their original group members [45], [46]. This process allows students to build conceptual understanding through discussion, re-explanation, and collaboration, ultimately supporting improved biology learning quality.

Theoretically, the success of the Jigsaw model can be explained through a social constructivism approach, which emphasizes the importance of social interaction in learning. When students discuss and exchange information with their groupmates, a process of knowledge elaboration occurs, helping to strengthen conceptual understanding [47], [48]. In the Protista topic, which is abstract and contains many scientific terms, the activity of explaining concepts among group members helps students grasp concepts in simpler, more understandable language. This contrasts with conventional learning, which tends to be teacher-centered, resulting in students receiving information passively.

In addition to cognitive aspects, the implementation of the Jigsaw model also has a positive impact on the development of students' attitudes and social skills. Through group discussions, students are trained to work together, take responsibility for their assignments, and improve their communication skills and self-confidence. Learning involving active interaction like this can create a more participatory and enjoyable classroom atmosphere, thus increasing student motivation to learn [49], [50]. Thus, the Jigsaw model is not only oriented towards academic achievement but also towards character development and 21st-century skills, which are essential in the modern learning process.

The results of this study also reinforce previous research findings that suggest cooperative learning is effective in improving understanding of biological concepts. However, this study provides a more specific contribution because it focuses on the topic of Protista, which has been relatively rarely studied in the context of Jigsaw learning. Protista material is quite complex, encompassing the classification, characteristics, and roles of diverse organisms. Therefore, the use of a learning model that fosters active student engagement is crucial to helping students understand the material more systematically and in-depth.

In terms of impact, this research provides practical implications for biology teachers in selecting more innovative and student-centered learning strategies. The Jigsaw model can be used as an alternative learning method to improve the quality of the teaching and learning process, especially for materials students find difficult. Furthermore, the implementation of this model has the potential to increase students' learning motivation, communication skills, and collaboration skills, which are essential for 21st-century learning. For schools, the results of this study can serve as a basis for encouraging the use of active learning models as part of efforts to improve the quality of education and overall student learning outcomes.

However, this study still has several limitations. The study was conducted in only one school with a limited sample size, so generalizing the results to a wider population requires caution. Furthermore, this study focused only on Protista material, so the effectiveness of the Jigsaw model on other biology materials cannot yet be fully understood. Another limitation lies in the relatively short duration of the study, which cannot yet describe the long-term effects of the Jigsaw model on student concept retention and skill development. Therefore, further research is recommended to involve a larger sample size, conduct a longer study period, and combine quantitative and qualitative approaches to obtain a more comprehensive picture of the effectiveness of the Jigsaw learning model.

4. CONCLUSION

Based on the research results obtained and the discussion presented in the previous chapter, it can be concluded that there is a difference in the increase in learning outcomes between students taught through jigsaw type cooperative learning and conventional learning on the concept of protists, as evidenced by the calculation of the final hypothesis test, namely $t_{count} > t_{table}$ (3.75>1.99). Future research is recommended to apply the Jigsaw learning model to other biology materials and involve a larger sample size to obtain more representative and broadly generalizable results. Furthermore, future research could examine the influence of the Jigsaw model on 21st-century skills, such as critical thinking, communication, and collaboration, in students over a longer period of time.

ACKNOWLEDGEMENTS

The author would like to thank all parties who provided support, assistance, and contributions to the implementation of this research. Thanks are extended to the school, teachers, and all students who participated in this research. Appreciation is also extended to the supervising lecturer and colleagues who provided input and guidance during the preparation of this article. Hopefully, this research will benefit the development of biology learning in the future.

AUTHOR CONTRIBUTIONS

Conceptualization, S.F. and N.V.; Methodology, S.F.; Software, S.F.; Validation, S.F., N.V., and F.G.; Formal Analysis, S.F.; Investigation, S.F.; Resources, N.V.; Data Curation, S.F.; Writing – Original Draft Preparation, S.F.; Writing – Review & Editing, N.V. and F.G.; Visualization, S.F.; Supervision, N.V.; Project Administration, F.G.; Funding Acquisition, N.V.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

Not applicable.

REFERENCES

[1] I. Irwan, A. Arnadi, and A. Aslan, "Developing critical thinking skills of primary school students through independent curriculum learning," *Indones. J. Educ.*, vol. 4, no. 3, pp. 788–803, 2024.
[2] P. Kwangmuang, S. Jarutkamolpong, W. Sangboonraung, and S. Daungtod, "The development of learning innovation to enhance higher order thinking skills for students in Thailand junior high schools," *Heliyon*, vol. 7, no. 6, pp. 1–13, 2021, doi: 10.1016/j.heliyon.2021.e07309.
[3] D. A. E. P. Sembiring and M. Yusuf, "How do students understand biological concepts ? A study on science literacy in basic education," *J. Sinar Edukasi*, vol. 6, no. 3, pp. 207–222, 2025.
[4] P. Y. Chen and Y. C. Liu, "Impact of ai robot image recognition technology on improving students' conceptual understanding of cell division and science learning motivation," *J. Balt. Sci. Educ.*, vol. 23, no. 2, pp. 208–220, 2024, doi: 10.33225/jbse/24.23.208.
[5] V. Deak and R. Santoso, "Learning strategies and applications in learning achievements," *Int. J. Soc. Manag. Stud.*, vol. 2, no. 4, pp. 159–167, 2021.
[6] D. H. Chang, M. P. C. Lin, S. Hajian, and Q. Q. Wang, "Educational design principles of using ai chatbot that supports self-Regulated learning in education: Goal setting, feedback, and personalization," *Sustain.*, vol. 15, no. 17, pp. 1–15, 2023, doi: 10.3390/su151712921.
[7] I. M. Astra, A. Henukh, and Algiranto, "Implementation of think pair share model in physics learning to determine

cognitive, affective and psychomotor learning outcomes and student responses," in *Journal of Physics: Conference Series*, 2021, pp. 1–8. doi: 10.1088/1742-6596/1876/1/012064.
[8] M. A. AlAfnan, "Enhancing educational outcomes using AlAfnan taxonomy: integrating cognitive, affective, and psychomotor domains," *Int. J. Eval. Res. Educ.*, vol. 14, no. 3, pp. 2419–2437, 2025, doi: 10.11591/ijere.v14i3.33147.
[9] I. V. Pavlova *et al.*, "An introductory biology research-rich laboratory course shows improvements in students' research skills, confidence, and attitudes," *PLoS One*, vol. 16, no. 12, pp. 1–27, 2021, doi: 10.1371/journal.pone.0261278.
[10] I. Tahir, V. Van Mierlo, V. Radauskas, W. Yeung, A. Tracey, and R. da Silva, "Blended learning in a biology classroom: Pre-pandemic insights for post-pandemic instructional strategies," *FEBS Open Bio*, vol. 12, no. 7, pp. 1286–1305, Jul. 2022, doi: 10.1002/2211-5463.13421.
[11] M. Treve, "Comparative analysis of teacher-centered and student-centered learning in the context of higher education: A co-word analysis," *Iberoam. J. Sci. Meas. Commun.*, vol. 4, no. 2, pp. 1–12, 2024, doi: 10.47909/ijsmc.117.
[12] B. D. S. Ghaleb, "Effect of exam-focused and teacher-centered education systems on students' cognitive and psychological competencies," *Int. J. Multidiscip. Approach Res. Sci.*, vol. 2, no. 02, pp. 611–631, 2024, doi: 10.59653/ijmars.v2i02.648.
[13] H. Hardianto, S. Mahanal, H. Susanto, and S. Prabaningtyas, "Protist literacy: A novel concept of protistlearning in higher education," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 20, no. 2, pp. 1–15, 2024, doi: 10.29333/ejmste/14157.
[14] H. Hardianto, S. Mahanal, H. Susanto, and S. Prabaningtyas, *Exploring protist literacy among university students': Findings from a recent survey*, no. Smic. Atlantis Press International BV, 2024. doi: 10.2991/978-94-6463-624-6_18.
[15] M. S. G. Sihombing and H. Pranoto, "Analysis of students' learning difficulties protist material," *J. Pelita Pendidik.*, vol. 8, no. 4, pp. 1–11, 2020.
[16] L. Khalifatunnisa and I. Mubarok, "The application of 7E learning cycle model based on multiple representations on understanding the concept of classification and communication skills in protist learning material," *J. Biol. Educ.*, vol. 12, no. 2, pp. 181–191, 2023, doi: 10.15294/jbe.v12i2.59432.
[17] R. M. Sølvik and A. E. H. Glenna, "Teachers' potential to promote students' deeper learning in whole-class teaching: An observation study in Norwegian classrooms," *J. Educ. Chang.*, vol. 23, no. 3, pp. 343–369, 2022, doi: 10.1007/s10833-021-09420-8.
[18] D. Harefa, "Strengthening mathematics and natural sciences education based on the Local wisdom of South Nias: Integration of traditional concepts in modern education," *Haga J. Pengabdi. Kpd. Masy.*, vol. 3, no. 2, pp. 63–79, 2024, doi: 10.57094/haga.v3i2.2347.
[19] M. Usman, I. N. S. Degeng, S. Utaya, and D. Kuswandi, "The influence of jigsaw learning model and discovery learning on learning discipline and learning outcomes," *Pegem Egit. ve Ogr. Derg.*, vol. 12, no. 2, pp. 166–178, 2022, doi: 10.47750/pegegog.12.02.17.
[20] F. P. Soedimardjono and P. P, "Cooperative learning model with jigsaw type improves students' sciences process skills and learning outcomes," *JPI (Jurnal Pendidik. Indones.*, vol. 10, no. 1, pp. 172–179, 2021, doi: 10.23887/jpi-undiksha.v10i1.25203.
[21] P. Sunasuan and U. Songserm, "Using advance organizer model to influence the meaningful learning of new concepts for esl learners in a collaborative classroom," *Arab World English J.*, vol. 12, no. 3, pp. 129–143, 2021, doi: 10.24093/awej/vol12no3.9.
[22] T. F. Silalahi and A. F. Hutauruk, "The application of cooperative learning model during online learning in the pandemic period," *Budapest Int. Res. Critics Inst. Humanit. Soc. Sci.*, vol. 3, no. 3, pp. 1683–1691, 2020, doi: 10.33258/birci.v3i3.1100.
[23] T. Suwartono and Y. Romdona, "The jigsaw learning model to promote engagement in the english language classroom: A teacher's reflection," *Acta Pedagog. Asiana*, vol. 3, no. 2, pp. 55–64, 2024, doi: 10.53623/apga.v3i2.401.
[24] Z. Widyanto, R. Qomarrullah, and S. Tebai, "The implementation of the jigsaw-type cooperative learning model to enhance students' motivation and participation in physical education," *J. Phys. Educ. Sport. Heal. Recreat.*, vol. 14, no. 32, pp. 679–685, 2025, doi: 10.15294/active.v14i2.28474.
[25] P.-H. Chen, "In-class and after-class lecture note-taking strategies," *Act. Learn. High. Educ.*, vol. 22, no. 3, pp. 245–260, Nov. 2021, doi: 10.1177/1469787419893490.
[26] A. E. Flanigan and S. Titsworth, "The impact of digital distraction on lecture note taking and student learning," *Instr. Sci.*, vol. 48, no. 5, pp. 495–524, Oct. 2020, doi: 10.1007/s11251-020-09517-2.
[27] B. Panjaitan, B. Sitompul, and M. B. Panjaitan, "Comparison of learning outcomes using information and communication technology media with conventional learning at iakn tarutung," *Int. Dev. Plan. Rev.*, vol. 22, no. 02, pp. 1789–1800, 2023.
[28] V. Bhardwaj, S. Zhang, Y. Q. Tan, and V. Pandey, "Redefining learning: Student-centered strategies for academic and personal growth," *Front. Educ.*, vol. 10, no. February, pp. 1–15, 2025, doi: 10.3389/feduc.2025.1518602.
[29] S. Rosamsi and F. Aryanti, "The implementation of discovery learning to improve scientific literacy in biology learning of protists," *JPBIO (Jurnal Pendidik. Biol.*, vol. 10, no. 2, pp. 430–436, 2025, doi: 10.31932/jpbio.v10i2.5464.
[30] Y. A. Kebede, F. K. Zema, G. M. Geletu, and S. A. Zinabu, "Cooperative learning instructional approach and student's biology achievement: A quasi-experimental evaluation of jigsaw cooperative learning model in secondary schools in gedeo zone, South Ethiopia," *SAGE Open*, vol. 15, no. 1, pp. 1–13, 2025, doi: 10.1177/21582440251318883.
[31] I. N. Ojekwu and B. O. Ogunleye, "Effects of jigsaw learning strategy on science students' performance and interest in biology in selected schools in rivers state, Nigeria," *Sapientia Found. J. Educ. Sci. Gend. Stud.*, vol. 2, no. 3, pp. 299–308, 2020.
[32] I. Rionard and P. taek Liunima, "The influence of jigsaw cooperative learning model on learning outcomes of biology protist material," *Haumeni J. Educ.*, vol. 4, no. 1, pp. 1–8, 2024, doi: 10.35508/haumeni.v4i1.14357.
[33] J. Jirana, M. Damayanti, R. Rahmadina, and R. Megawati, "Comparison of cooperative learning models of reciprocal

teaching type and cooperative jigsaw type on students' learning outcomes in animalia material class x mipa sma negeri 1 tapalang," *J. Penelit. Pendidik. IPA*, vol. 11, no. 5, pp. 398–407, 2025, doi: 10.29303/jppipa.v11i5.11021.

[34] F. González-Alonso, F. D. Guillén-Gámez, and R. M. de Castro-Hernández, "Methodological analysis of the effect of an antibullying programme in secondary education through communicative competence: a pre-test—post-test study with a control-experimental group," *Int. J. Environ. Res. Public Health*, vol. 17, no. 9, pp. 1–16, 2020, doi: 10.3390/ijerph17093047.

[35] A. Tanhan, M. A. Karaman, and A. Nalbant, "The effect of counselling on anxiety level from the perspective of ecological systems theory: A quasi-experimental pre-test-post-test control group study," *Int. J. Psychol. Educ. Stud.*, vol. 7, no. 3, pp. 58–69, 2020, doi: 10.17220/ijpes.2020.03.006.

[36] K. M. Q. Magnone and E. J. Yezierski, "Beyond convenience: A case and method for purposive sampling in chemistry teacher professional development research," *J. Chem. Educ.*, vol. 101, no. 3, pp. 718–726, 2024, doi: 10.1021/acs.jchemed.3c00217.

[37] O. Tajik, J. Golzar, and S. Noor, "Purposive sampling," *Int. J. Educ. Lang. Stud.*, vol. 2, no. 2, pp. 1–9, 2024.

[38] N. Azizah, E. Istiyono, and I. Wilujeng, "Development of student cognitive learning outcomes tests based on differentiated learning," *J. Penelit. Pendidik. IPA*, vol. 10, no. 1, pp. 194–200, 2024, doi: 10.29303/jppipa.v10i1.5080.

[39] W. Sukmawati, S. L. Handayani, and Y. Yeni, "Is conceptual learning based on conceptual change text (CCT) effectively applied to pgsd students science class?," *J. Inov. Pendidik. IPA*, vol. 7, no. 2, pp. 171–181, Mar. 2022, doi: 10.21831/jipi.v7i2.44034.

[40] S. Saprudin and A. T. Pratama, "The effect of website-based digital learning media on students' cognitive learning outcomes in class x biology material," *Biosf. J. Pendidik. Biol.*, vol. 18, no. 1, pp. 138–147, 2025, doi: 10.21009/biosferjpb.49284.

[41] S. Demir, "Comparison of normality tests in terms of sample sizes under different skewness and kurtosis coefficients," *Int. J. Assess. Tools Educ.*, vol. 9, no. 2, pp. 397–409, 2022, doi: 10.21449/ijate.1101295.

[42] U. Knief and W. Forstmeier, "Violating the normality assumption may be the lesser of two evils," *Behav. Res. Methods*, vol. 53, no. 6, pp. 2576–2590, 2021, doi: 10.3758/s13428-021-01587-5.

[43] Y. Wang, "Affective state analysis during online learning based on learning behavior data," *Technol. Knowl. Learn.*, vol. 28, no. 3, pp. 1063–1078, Sep. 2023, doi: 10.1007/s10758-022-09597-8.

[44] D. Huang and W. Zhang, "Research on learning state based on students' attitude and emotion in class learning," *Sci. Program.*, vol. 2021, pp. 1–11, Dec. 2021, doi: 10.1155/2021/9944176.

[45] O. C. Drouet, V. Lentillon-Kaestner, and N. Margas, "Effects of the Jigsaw method on student educational outcomes: Systematic review and meta-analyses," *Front. Psychol.*, vol. 14, pp. 1–19, 2023, doi: 10.3389/fpsyg.2023.1216437.

[46] B. R. Hiremath, A. S, D. Deepthi, V. Hiregoudar, and P. S. Patil, "Effectiveness of jig-saw classroom versus tutorial method of small group teaching in improving the learning of undergraduate students," *Int. J. Life Sci. Biotechnol. Pharma Res.*, vol. 14, no. 1, pp. 693–697, 2025, doi: 10.69605/ijlbpr_14.1.2025.119.

[47] R. Joshi, D. Hadley, S. Nuthikattu, S. Fok, L. Goldbloom-Helzner, and M. Curtis, "Concept mapping as a metacognition tool in a problem-solving-based BME course during in-person and online instruction," *Biomed. Eng. Educ.*, vol. 2, no. 2, pp. 281–303, 2022, doi: 10.1007/s43683-022-00066-3.

[48] A. H. Schoenfeld, "Reframing teacher knowledge: a research and development agenda," *ZDM*, vol. 52, no. 2, pp. 359–376, May 2020, doi: 10.1007/s11858-019-01057-5.

[49] Z. Abidin and N. Muhammad, "Effective classroom management as a quick solution to improve student participation and motivation in the learning process," *Zabags Int. J. Educ.*, vol. 2, no. 2, pp. 75–88, 2024, doi: 10.61233/zijed.v2i2.22.

[50] H. A. Ismail *et al.*, "Sustainable healthcare futures: how digital leadership stimulates nurses' green creativity: A quasi-experimental study," *BMC Nurs.*, vol. 24, no. 1, pp. 1–11, 2025, doi: 10.1186/s12912-025-02906-3.