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Innovative Chemistry Learning: The Impact of the Jigsaw Cooperative Model on Students’ Understanding of Reaction Rate Concepts

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ABSTRACT

Purpose of the study: This study aims to determine the effect of the Jigsaw type cooperative learning model on students' chemistry learning outcomes on the concept of reaction rate by comparing it with the expository learning method at the high school level.

Methodology: Quasi-experimental method, Only Posttest Control Group Design, purposive sampling technique, multiple-choice test instrument (22 questions), validity and reliability test using ANATES software, Liliefors normality test, Fisher homogeneity test, and t-test statistical analysis at a significance level of $\alpha = 0.05$.

Main Findings: The average value of the experimental group (70.15) was higher than the control group (57.87). The results of the statistical test showed that $t_{count} = 4.47$ was greater than $t_{table} = 1.999$, so there was a significant difference. The Jigsaw Model was proven to improve student learning outcomes on the concept of reaction rate.

Novelty/Originality of this study: This research focuses on the application of the Jigsaw model to the under-researched concept of reaction rate. This study provides empirical evidence of its effectiveness in chemistry learning and enriches innovative learning strategies to enhance conceptual understanding and student engagement.

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1. INTRODUCTION

Education is an important factor in improving the quality of human resources, especially in facing the challenges of developments in science and technology [1], [2]. In the context of learning in schools, the success of the educational process is largely determined by the effectiveness of the learning strategies and models used by teachers [3], [4]. Learning chemistry as part of science is often considered difficult by students because it involves abstract concepts and mathematical calculations [5], [6]. One of the most complex chemistry topics is the concept of reaction rates, which requires a deep understanding of the factors that influence them. Therefore, innovations in learning models are needed to improve student understanding and learning outcomes.

Student learning outcomes are an important indicator in assessing the success of the learning process that has been carried out [7], [8]. However, in reality, many students still have difficulty understanding chemistry concepts optimally. This is due to the use of learning methods that tend to be conventional and teacher-centered. [9], [10]. Learning models such as lectures often make students less active and less involved in the learning process

[11], [12]. This condition has an impact on low student learning outcomes, especially in material that requires conceptual understanding such as reaction rates.

One alternative learning model that can be used to improve student learning outcomes is the cooperative learning model [13], [14]. This model emphasizes cooperation between students in small groups to achieve shared learning goals [15], [16]. Through social interaction and discussion, students can help each other understand difficult material. Cooperative learning models can also improve students' communication and collaboration skills [17], [18]. Thus, this model is considered capable of creating a more active and enjoyable learning atmosphere.

One type of cooperative learning model that is quite effective is the Jigsaw model [19], [20]. The Jigsaw model requires students to become "experts" in a specific subtopic before sharing their knowledge with other group members. This process encourages students to take greater responsibility for their own learning [21], [22]. Furthermore, students are trained to convey information clearly to their group mates. This mechanism is expected to significantly improve students' understanding of the learning material [23], [24].

The application of the Jigsaw model to chemistry learning is expected to address various challenges faced by students [25], [26]. This model allows students to actively engage in the learning process through discussion and collaboration [27], [28]. In the reaction rate topic, students can exchange information about factors that influence reaction speed. This can help students understand abstract concepts more concretely. Thus, the use of the Jigsaw model has the potential to optimally improve student learning outcomes [29], [30].

Several previous studies have shown that the Jigsaw model has a positive influence on student learning outcomes [19], [31]. However, most of these studies have focused on other subjects or different chemistry topics. Furthermore, the implementation of the Jigsaw model on the concept of reaction rates has not been extensively studied. This material is quite difficult and requires an appropriate learning approach. Therefore, further research is needed to assess the effectiveness of the Jigsaw model on this topic.

Based on this description, there is a gap in research related to the application of the Jigsaw cooperative learning model to the concept of reaction rates, which is still limited. This research has a novelty that lies in the integration of the Jigsaw cooperative learning model with the conceptual characteristics of reaction rate material in chemistry learning, which not only focuses on improving quantitative learning outcomes, but also on efforts to strengthen students' conceptual understanding of abstract concepts. In contrast to previous studies that generally examine the effectiveness of the Jigsaw model in general or on materials other than chemical kinetics, this study specifically places the concept of reaction rate as a study context by considering the complexity of chemical representations (macroscopic, microscopic, and symbolic) which are often a source of student learning difficulties.

In addition, this study contributes to examining how social interactions in cooperative learning can facilitate the process of constructing chemical knowledge more meaningfully. The urgency of this research is based on the still low understanding of chemical concepts by students due to the dominant use of conventional learning methods that do not involve active student participation. Therefore, learning innovations are needed that not only improve learning outcomes but also can help students build a deep understanding of concepts. Thus, this research is important to be conducted as an effort to present alternative learning strategies that are more effective and relevant in improving the quality of chemistry learning in schools. Therefore, this research is expected to provide solutions to low student learning outcomes and serve as a reference for teachers in selecting appropriate learning models.

2. RESEARCH METHOD

2.1. Type of Research

This study employed a quasi-experimental approach, a research method that does not fully meet all the criteria for a pure experiment [32], [33]. This approach was applied to groups with relatively homogeneous characteristics, then divided into two groups as the objects of observation. In this study, both groups were assumed to have equal initial abilities, so any differences in results were more attributable to the treatment administered. Thus, variations in the dependent variable can be interpreted as the impact of the treatment on the independent variable, rather than differences in subject characteristics.

The first group in this study was treated with the Jigsaw cooperative learning model, while the second group was treated using conventional learning with an expository method. The comparison between the two groups aimed to determine the effectiveness of the applied learning model on student learning outcomes [34], [35]. The research design used was a Only Posttest Control Group Design, a research design that uses only a final test to measure the results of the treatment in each group.

Table 1. Research Design

Group	Treatment	Posttest
Experimental	X_E	T
Control	X_C	T

2.2. Population and Sample

A population is the entirety of the subjects focused on in a study. Population determination aims to determine the sample size and limit the scope of generalization of research results [36], [37]. In this study, the population was divided into two categories: the target population and the accessible population. The target population included all eleventh-grade students at Nusa Putra Senior High School, Tangerang. Meanwhile, the accessible population included all eleventh-grade students in the science program at the school.

The sample is a subset of the population selected to represent the entire research subject. The sampling technique used in this study was purposive sampling, which involves selecting samples based on specific considerations without using simple random sampling [38], [39]. The sample size was 80 students divided into two classes. Class XI Science 1 was designated as the control class, while Class XI Science 2 was designated as the experimental class.

2.3. Research Instruments

A research instrument is a tool used by researchers to obtain the necessary data. In this study, the instrument used was a test. A test is a set of questions, exercises, or other tools designed to measure an individual's or group's abilities, whether in terms of knowledge, skills, or intellectual abilities. Furthermore, a test can also be understood as a systematic procedure for measuring and evaluating in education through the provision of tasks or a series of instructions that must be completed by students to produce a specific score [40], [41]. The test instrument used in this study aims to measure the cognitive aspects of student learning outcomes in the topic of reaction rates. The test format used was multiple-choice with five answer alternatives. A total of 22 questions were designed to assess students' comprehensive understanding of the concepts being studied.

2.4. Data Analysis Techniques

In this study, hypothesis testing was conducted using a t-test with a significance level of $\alpha = 0.05$. Before conducting the hypothesis test, prerequisite analysis tests were first conducted, namely the normality test and the homogeneity test. These two tests aim to ensure that the data meets the assumptions required for using the t-test. By meeting these assumptions, the analysis results are more valid and accountable. Therefore, this stage is a crucial part of the quantitative research data analysis process.

The normality test is used to determine whether the sample data comes from a normally distributed population [42], [43]. In this study, the normality test was conducted using the Liliefors method. The initial step was to sort the data from smallest to largest, then calculate the standard score (Zi) for each data point. Next, the probability value was determined based on the normal distribution table for each Zi and the cumulative proportion was calculated. The difference between the theoretical probability value and the empirical proportion was then calculated, and the maximum value of this difference was expressed as Lo.

The obtained Lo value was then compared with the L_{table} value at a certain significance level. If the Lo value was less than L_{table}, the data were considered normally distributed. Conversely, if L is greater than L, the data is not normally distributed. Therefore, the results of this test serve as the basis for determining the type of advanced statistical test to be used. The normality test ensures that the data meets the distribution assumptions required in parametric analysis [44].

Next, a homogeneity test is conducted to determine whether the variances of the two data groups are equal. The test used in this study is the Fisher exact test (F test) with a significance level of $\alpha = 0.05$. The test is performed by comparing the largest variance with the smallest variance of the two groups. The calculated F_{value} is then compared with the F_{table} to form the basis for decision-making. If the calculated F is smaller than the F_{table}, the two groups have homogeneous variances. Conversely, if the calculated F_{value} is greater than the F_{table}, the variances of the two groups are considered non-homogeneous. The results of this homogeneity test are crucial in selecting the t-test formula to be used. If the data are homogeneous, a t-test with combined variances is used. However, if the data are not homogeneous, a t-test with separate variances is used. Therefore, a homogeneity test is a crucial step before conducting a hypothesis test.

Hypothesis testing was conducted to determine whether there were significant differences between the chemistry learning outcomes of students taught using the Jigsaw cooperative learning model and those taught using the expository method. If the normality test results indicated a normal distribution between the two groups, the analysis continued with a t-test. The t-test was conducted by comparing the average scores of the two groups based on a formula consistent with homogeneity of variance. The calculated t-value was then compared with the t-table at a significance level of $\alpha = 0.05$.

The decision-making criteria in the hypothesis test were to accept H_0 if the calculated t-value was less than the t-table, indicating no significant difference between the two groups. Conversely, H_0 was rejected if the calculated t-value was greater than the t-table, indicating a significant difference between the learning outcomes of the two groups. Thus, the results of this test will provide conclusions regarding the effect of the Jigsaw cooperative learning model on student chemistry learning outcomes.

3. RESULTS AND DISCUSSION

Student learning outcomes in the cognitive aspect were determined based on the results of a 22-question multiple-choice test administered after the lesson. This multiple-choice test instrument had previously been tested for its validity and reliability in class XII Science 1 at Nusa Putra Senior High School, Tangerang. The items were also tested for their difficulty level and discrimination power, making this instrument suitable for use in this study.

Table 1. Summary of Learning Outcome Scores for the Reaction Rate Concept in the Experimental Class and Control Class

Data	Experiment	Control
N	40	40
Average	70.15	57.87
SD	12.17	12.8

Based on the research results, the average value of students' chemistry learning outcomes on the concept of Reaction Rate was obtained, namely in the experiment of 70.15 while the control class was 57.87. This shows that the average chemistry learning outcomes of students in the experimental class were greater than those in the control class.

3.1. Normality Test

Before further data analysis, a normality test was conducted on the learning outcomes in both research groups. This test aims to determine whether the data obtained follows a normal distribution or not. The criterion used in this test is to compare the calculated L_{value} with the L_{table}. Data are considered normally distributed if the calculated L_{value} is smaller than the L_{table} at the specified significance and confidence levels. Conversely, if the calculated L_{value} is greater than the L_{table}, then the data are not normally distributed.

Table 2. Normality Test Results

Statistics	Experiment	Control
N	40	40
X	70.15	57.87
SD	12.17	12.8
L_{count}	0.089	0.1332
L_{table}	0.14	0.14

Testing was carried out using the Liliefors test at a significance level of 95% ($\alpha = 0.05$) for $n = 40$. From the table, it can be concluded that both groups are normally distributed because they meet the criteria of $L_{count} < L_{table}$.

3.2. Homogeneity Test

After both research samples were declared normally distributed, the next step was to test for equality of variance (homogeneity) using the two-variance homogeneity test. This test was conducted by comparing the calculated F_{value} with the F_{table} as the basis for decision-making. The criteria used were: H_0 is accepted if the calculated F is less than the F_{table}, indicating that the data have homogeneous variance. Conversely, H_0 is rejected if the calculated F is greater than the F_{table}, indicating that the data are not homogeneous.

Based on the calculation results, the variance values for each group were obtained: $S1^2 = 163.8$ and $S2^2 = 148.1$. From these two values, the calculated F_{value} was 1.10. This value was then compared with the F_{table} of 1.735 at the 95% significance level ($\alpha = 0.05$). Because the calculated F is less than the F_{table}, it can be concluded that the two groups have homogeneous variance. Thus, the data meets one of the requirements for hypothesis testing using the t-test.

3.3. Hypothesis Testing

Hypothesis testing was conducted after the results of the normality and homogeneity tests showed that both sample groups were normally distributed and had homogeneous variances. To test the null hypothesis (H_0), which stated that there was no effect of the use of the Jigsaw cooperative learning model on students' chemistry learning outcomes, a t-test was used at a significance level of $\alpha = 0.05$. The testing criteria used were that H_0 was accepted if the t_{count} value was smaller than $t_{ta\beta}$le, and H_0 was rejected if t_{count} value was greater than $t_{ta\beta el}$.

Based on the calculation results, the t_{count} value was 4.47. Meanwhile, from the t-distribution table at a significance level of $\alpha = 0.05$, the $t_{ta\beta}$le value is 1.999. Because the t_{count} value is greater than $t_{ta\beta}$le, H_0 is rejected. This indicates that there is a significant influence of the use of the Jigsaw type cooperative learning model on students' chemistry learning outcomes. The comparison of the t-test results between the experimental group and the control group can be seen in the following table.

Table 3. Results of the T-Test of Chemistry Learning Outcomes of Students in the Experimental Group and the Control Group

Variables	Number of Samples	t_{count}	t_{table}	Conclusion
Chemistry learning outcomes of students in the experimental group and control group	80	4.47	1.999	Reject H_0

Based on the table above, it is known that $t_{count} = 4.47$ with a significance level of $\alpha = 0.05$, the t_{table} is 1.999, so $t_{count} > t_{table}$ and rejects H_0. This means that there is a significant influence between students taught with the Jigsaw type cooperative learning model in the experimental group and the Expository method in the control group. Thus, the study can test the truth of the hypothesis, namely that in the application of the Jigsaw type cooperative learning model there is a positive influence on chemistry learning outcomes. This fact is in accordance with field conditions, namely the experimental class is quicker to understand the chemistry lesson material on the concept of reaction rates.

The Jigsaw cooperative learning model is theoretically rooted in a social constructivist approach, which emphasizes that knowledge is built through social interaction and collaboration between students [45], [46]. In the context of chemistry learning, this approach is highly relevant because many chemical concepts, including reaction rates, are abstract and require in-depth cognitive elaboration. Through the Jigsaw learning mechanism, students not only passively receive information but also actively engage in the knowledge-building process through discussions, exchange of ideas, and re-explaining concepts to their group mates. This process allows for a more meaningful reconstruction of knowledge compared to teacher-centered learning.

The characteristics of reaction rate material, which involves concepts such as factors influencing reaction speed, activation energy, and the relationships between chemical variables, require students to connect various chemical representations: macroscopic, microscopic, and symbolic. In this regard, the Jigsaw model provides space for students to study specific subconcepts in greater depth as "experts," then convey their understanding to other group members. This process can help students organize information and integrate various chemical representations, resulting in a more comprehensive understanding of the concept [47], [48]. Furthermore, mutual teaching among students also has the potential to reduce misconceptions that often arise in chemical kinetics.

From a cognitive perspective, Jigsaw cooperative learning encourages elaboration, the process of broadening and deepening understanding through explanation, argumentation, and discussion [49]. When students explain a concept to a peer, they indirectly process information at a higher level, thereby strengthening their cognitive structures. This activity aligns with the principle of "learning by teaching," which has been proven effective in improving conceptual understanding. In chemistry learning, this strategy is crucial because students often struggle to understand cause-and-effect relationships in chemical phenomena that cannot be directly observed.

Beyond cognitive aspects, the Jigsaw model also contributes to improving students' social skills and scientific communication. Learning chemistry requires not only conceptual mastery but also the ability to communicate scientific ideas clearly and systematically [18], [50]. Through group discussions and presentations among members, students are trained to convey their understanding using appropriate scientific language. This interaction also allows for negotiation of meaning, where students can clarify misunderstandings through peer feedback. Thus, learning becomes more interactive and student-centered.

The implementation of the Jigsaw model in chemistry learning can also be seen as an effort to create a more active and participatory learning environment. Unlike expository methods, which tend to be one-way, this model positions students as the primary subjects in the learning process. Active student involvement in each stage of learning allows them to develop a sense of responsibility for their learning [51], [52]. This is crucial for developing learning independence and increasing students' intrinsic motivation in learning chemistry. Conceptually, the Jigsaw cooperative learning model has strong potential to support more meaningful chemistry learning, particularly in abstract material such as reaction rates. The integration of collaborative activities, cognitive elaboration processes, and social interaction makes this model a relevant alternative learning strategy for improving the quality of chemistry learning at the secondary school level.

This research has significant implications for the development of chemistry learning, particularly in the application of the Jigsaw cooperative learning model as an alternative, more active, student-centered learning strategy. Pedagogically, the use of this model has the potential to encourage student engagement in the learning process, improve scientific communication skills, and facilitate the construction of a more meaningful understanding of chemical concepts, particularly in abstract material such as reaction rates. Furthermore, this research provides practical contributions for chemistry teachers in designing more interactive and collaborative learning and can serve as a reference in implementing learning approaches that support the development of 21stcentury skills. Academically, the findings of this study enrich research in the field of chemistry education, particularly regarding the effectiveness of cooperative learning models in improving the quality of learning on the topic of chemical kinetics.

However, this study has several limitations that require consideration. First, the research design, which used an Only Posttest Control Group Design, did not allow researchers to directly measure students' initial abilities, so potential initial differences between groups could not be fully controlled for. Second, this study focused solely on the cognitive aspect of learning outcomes, thus failing to examine other aspects such as qualitative conceptual understanding, science process skills, or students' scientific attitudes in depth. Third, the study's limited scope, limited to a single school with a limited sample size, limits the generalizability of the results to a broader context. Furthermore, the implementation of the learning model is also influenced by external factors such as classroom conditions, learning time, and the role of the teacher, which cannot be fully controlled. Therefore, future research is recommended to use a more robust experimental design, involve a wider sample, and integrate various assessment aspects to obtain a more comprehensive picture of the effectiveness of learning models in chemistry education.

4. CONCLUSION

Based on the research results and data analysis presented in the previous chapter, several conclusions can be drawn as follows. First, the average value of student learning outcomes in the experimental class was 70.15, higher than the control class which obtained an average of 57.87. This shows that the application of the Jigsaw type cooperative learning model provides better results for student chemistry learning achievement compared to conventional learning methods. Second, based on the results of the hypothesis testing, the t_{count} value was 4.47, while the t_{table} value at a significance level of 0.05 was 1.999. Because t_{count} was greater than $t_{ta\beta el}$, the null hypothesis (H_0) was rejected and the alternative hypothesis (H_a) was accepted. Thus, it can be concluded that the use of the Jigsaw type cooperative learning model has a significant influence on students' chemistry learning outcomes, especially on the material on reaction rates. Further research is also recommended to examine the influence of the Jigsaw model on students' conceptual understanding using diagnostic instruments such as two-tier or three-tier tests so that misconceptions can be identified in more depth.

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AUTHOR CONTRIBUTIONS

Conceptualization, M.D.A.; Methodology, M.D.A.; Software, M.D.A.; Validation, M.D.A.; Formal Analysis, M.D.A.; Investigation, M.D.A.; Resources, M.D.A.; Data Curation, M.D.A.; Writing – Original Draft Preparation, M.D.A.; Writing – Review & Editing, M.D.A.; Visualization, M.D.A.; Supervision, M.D.A.; Project Administration, M.D.A.; Funding Acquisition, M.D.A.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

Not applicable”

REFERENCES

[1] N. M. Tri and L. N. Minh, “Factors affecting the role of education and training in human resource development of Vietnam,” *Int. J. Health Sci. (Qassim).*, vol. 6, no. S1, pp. 1–14, 2022, doi: 10.53730/ijhs.v6ns1.4742.

[2] M. A. Haidar, M. Hasanah, and M. A. Ma’arif, “Educational challenges to human resource development in islamic education institutions,” *Munaddhomah J. Manaj. Pendidik. Islam*, vol. 3, no. 4, pp. 366–377, 2022, doi: 10.31538/munaddhomah.v3i4.309.

[3] M. Saqr, W. Matcha, N. A. Uzir, J. Jovanović, D. Gašević, and S. López-Pernas, “Transferring effective learning strategies across learning contexts matters: A study in problem-based learning,” *Australas. J. Educ. Technol.*, vol. 39, no. 3, pp. 35–57, 2023, doi: 10.14742/ajet.8303.

[4] Z. Ersozlu, S. Taheri, and I. Koch, “A review of machine learning methods used for educational data,” *Educ. Inf. Technol.*, vol. 29, no. 16, pp. 22125–22145, 2024, doi: 10.1007/s10639-024-12704-0.

[5] C. Stroumpouli and G. Tsaparlis, “Chemistry students’ conceptual difficulties and problem solving behavior in chemical kinetics, as a component of an introductory physical chemistry course,” *Chem. Teach. Int.*, vol. 4, no. 3, pp. 279–296,

2022, doi: 10.1515/cti-2022-0005.

[6] T. M. Clark, E. Anderson, N. M. Dickson-Karn, C. Soltanirad, and N. Tafini, “Comparing the performance of college chemistry students with chatGPT for calculations involving acids and bases,” *J. Chem. Educ.*, vol. 100, no. 10, pp. 3934–3944, Oct. 2023, doi: 10.1021/acs.jchemed.3c00500.

[7] H. Goss, “Student learning outcomes assessment in higher education and in academic libraries: A review of the literature,” *J. Acad. Librariansh.*, vol. 48, no. 2, p. 102485, Mar. 2022, doi: 10.1016/j.acalib.2021.102485.

[8] M. Hooda, C. Rana, O. Dahiya, A. Rizwan, and M. S. Hossain, “Artificial intelligence for assessment and feedback to enhance student success in higher education,” *Math. Probl. Eng.*, vol. 2022, pp. 1–19, May 2022, doi: 10.1155/2022/5215722.

[9] N. Martin-Alguacil, L. Avedillo, R. Mota-Blanco, and M. Gallego-Agundez, “Student-centered learning: Some issues and recommendations for its implementation in a traditional curriculum setting in health sciences,” *Educ. Sci.*, vol. 14, no. 11, pp. 1–26, 2024, doi: 10.3390/educsci14111179.

[10] E. Balla, “Teacher centered method vs student centered method of teaching in teaching english: Critical study,” *Interdiscip. J. Res. Dev.*, vol. 10, no. 3, pp. 60–65, 2023, doi: 10.56345/ijrdv10n309.

[11] A. Hussein, S. Dzaiy, and S. A. Abdullah, “The use of active learning strategies to foster effective teaching in higher education institutions,” *Zanco J. Humanit. Sci.*, vol. 28, no. 4, pp. 328–351, 2024, doi: 10.21271/zjhs.28.4.18.

[12] S. Sutrisno and J. A. Nasucha, “Islamic religious education project-based learning model to improve student creativity,” *At-tadzkir Islam. Educ. J.*, vol. 1, no. 1, pp. 13–22, 2022, doi: 10.59373/attadzkir.v1i1.3.

[13] N. Indrawati and A. Y. D. Desky, “How to improve elementary school student learning outcomes by implementing the articulation type cooperative learning model?,” *J. Indones. Prim. Sch.*, vol. 1, no. 2, pp. 32–37, 2024, doi: 10.62945/jips.v1i2.96.

[14] B. Öztürk, “The effect of cooperative learning models on learning outcomes: A second-order meta-analysis,” *Educ. Policy Anal. Strateg. Res.*, vol. 18, no. 3, pp. 273–296, 2023, doi: 10.29329/epasr.2023.600.13.

[15] X. Yang, “A historical review of collaborative learning and cooperative learning,” *TechTrends*, vol. 67, no. 4, pp. 718–728, 2023, doi: 10.1007/s11528-022-00823-9.

[16] K. Karman, M. Maslani, R. Anwar, R. A. Yudhiantara, and D. Djubaedi, “Enhancing student learning outcomes in the qur’an interpretation course through the implementation of the Start from reading (SFR) cooperative learning model,” *Nazhruna J. Pendidik. Islam*, vol. 7, no. 1, pp. 156–170, 2024, doi: 10.31538/nzh.v7i1.4657.

[17] Y. Yennita, A. Al Fatihah, Z. Zulirfan, and K. Osman, “The change in students’ communication and collaboration skills through time token cooperative learning model,” *J. Pendidik. IPA Indones.*, vol. 13, no. 2, pp. 313–324, 2024, doi: 10.15294/n77t7q82.

[18] C. N. D. Putri, R. N. Sedyati, and M. Zulianto, “Students’ collaboration and communication skills with problem-based learning model,” *J. Inov. dan Teknol. Pembelajaran*, vol. 10, no. 3, pp. 225–233, 2025, doi: 10.17977/um031v10i32023p225.

[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] H. Hamzah, K. Khairiah, S. Tambak, M. L. Hamzah, and A. A. Purwati, “Implementation of Jigsaw type cooperative learning method to increase student learning activity in Fiqh learning during COVID-19,” *Int. J. Health Sci. (Qassim).*, vol. 6, no. April, pp. 4438–4446, 2022, doi: 10.53730/ijhs.v6ns1.5914.

[21] I. Sasson and I. Yehuda, “Redesigning the learning environment: Student motivation and personal responsibility for learning,” *Curr. Psychol.*, vol. 42, no. 35, pp. 31251–31262, Dec. 2023, doi: 10.1007/s12144-022-04140-5.

[22] 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.

[23] W. Wang, H. Lee, C. Lin, P. Li, Y. Huang, and T. Wu, “Enhancing students’ learning outcomes in self-regulated virtual reality learning environment with learning aid mechanisms,” *Br. J. Educ. Technol.*, vol. 56, no. 1, pp. 366–387, Jan. 2025, doi: 10.1111/bjet.13512.

[24] E. Hariyono, I. A. Rizki, D. A. Lestari, N. F. Citra, A. N. Islamiyah, and A. I. Agusty, “Engklek game ethnoscience-based learning material (egeblm) to improve students’ conceptual understanding and learning motivation,” *J. Pendidik. IPA Indones.*, vol. 12, no. 4, pp. 635–647, 2023, doi: 10.15294/jpii.v12i4.43941.

[25] M. R. Apsari, “Improving chemistry learning outcomes with jigsaw for biology education students,” *IJCER (International J. Chem. Educ. Res.*, vol. 9, no. 1, pp. 22–30, 2025, doi: 10.20885/ijcer.vol9.iss1.art3.

[26] S. Rahmawati, D. Poba, M. Magfirah, and K. Burase, “Application of cooperative learning jigsaw model to improve student’s learning achievement in chemistry learning,” *J. Akad. Kim.*, vol. 11, no. 1, pp. 39–45, Feb. 2022, doi: 10.22487/j24775185.2022.v11.i1.pp39-45.

[27] S. Gopinathan, A. H. Kaur, S. Veeraya, and M. Raman, “The role of digital collaboration in student engagement towards enhancing student participation during COVID-19,” *Sustain.*, vol. 14, no. 11, pp. 1–23, 2022, doi: 10.3390/su14116844.

[28] A. Sølvberg and M. Rismark, “Student collaboration in student active learning,” *Proc. Int. Conf. Futur. Teach. Educ.*, vol. 2, no. 1, pp. 74–81, 2023, doi: 10.33422/icfte.v2i1.73.

[29] V. Almaghfiroh, H. Wang, and L. F. Purposari, “Application of the jigsaw learning model to improve student learning outcomes in mathematics,” *Int. J. Educ. Curric. Appl.*, vol. 7, no. 1, pp. 51–58, 2024, doi: 10.31764/ijeca.v7i1.22499.

[30] Y. Affandi, A. Darmuki, and A. Hariyadi, “The evaluation of jidi (jigsaw discovery) learning model in the course of qur’an tafsir,” *Int. J. Instr.*, vol. 15, no. 1, pp. 799–820, 2022, doi: 10.29333/iji.2022.15146a.

[31] J. Jamaluddin, R. R. Febyanti, and A. R. Alamsyah, “The effect of the jigsaw learning model on student learning outcomes at the agricultural vocational high school,” in *Vocational Education International Conference*, 2023, pp. 488–494. [Online]. Available: https://proceeding.unnes.ac.id/veic/article/view/2880#:~:text=After applying the jigsaw learning model%2C student learning,increase the effectiveness of the student learning process.

[32] J. S. O. Zajić and J. Maksimović, “Quasi-experimental research as an epistemological-methodological approach in education research,” *Int. J. Cogn. Res. Sci. Eng. Educ.*, vol. 10, no. 3, pp. 177–183, 2022, doi: 10.23947/2334-8496-2022-10-3-177-183.

[33] 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.

[34] A. Muthik, A. Muchyidin, and A. R. Persada, “The effectiveness of students’ ;earning motivation on learning outcomes using the reciprocal teaching learning model,” *J. Gen. Educ. Humanit.*, vol. 1, no. 1, pp. 21–30, 2022, doi: 10.58421/gehu.v1i1.7.

[35] I. Fitrianto, S. ’Aimah, R. Hamid, and A. Mulalic, “The effectiveness of the learning strategy ‘think, talk, write’ and snowball for improving learning achievement in lessons insya’ at Islamic Boarding School Arisalah,” *Int. J. Post Axial Futur. Teach. Learn.*, vol. 1, no. 1, pp. 13–22, 2023, doi: 10.59944/postaxial.v1i1.142.

[36] F. Scârneci-Domnişoru, “From sample to population generalization in qualitative research,” *Qual. Rep.*, vol. 29, no. 8, pp. 2362–2386, 2024, doi: 10.46743/2160-3715/2024.7039.

[37] A. Zrineh, M. Al-Usta, and A. Alwawi, “Sampling methods and sample size determination in clinical research: An educational review,” *J. Gen. Fam. Med.*, vol. 27, no. 1, pp. 1–9, Jan. 2026, doi: 10.1002/jgf2.70096.

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

[39] 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.

[40] D. Lee and E. Palmer, “Prompt engineering in higher education: a systematic review to help inform curricula,” *Int. J. Educ. Technol. High. Educ.*, vol. 22, no. 7, pp. 1–22, 2025, doi: 10.1186/s41239-025-00503-7.

[41] M. Jukiewicz, “The future of grading programming assignments in education: The role of ChatGPT in automating the assessment and feedback process,” *Think. Ski. Creat.*, vol. 52, no. July 2023, pp. 1–9, 2024, doi: 10.1016/j.tsc.2024.101522.

[42] F. Habibzadeh, “Data distribution: Normal or abnormal?,” *J. Korean Med. Sci.*, vol. 39, no. 3, pp. 1–8, 2024, doi: 10.3346/jkms.2024.39.e35.

[43] M. Fiandini, A. B. D. Nandiyanto, D. F. Al Husaeni, D. N. Al Husaeni, and M. Mushiban, “How to calculate statistics for significant difference test using spss: understanding students comprehension on the concept of steam engines as power plant,” *Indones. J. Sci. Technol.*, vol. 9, no. 1, pp. 45–108, 2024, doi: 10.17509/ijost.v9i1.64035.

[44] J. Kostanek, K. Karolczak, W. Kuliczkowski, and C. Watala, “Bootstrap method as a tool for analyzing data with atypical distributions deviating from parametric assumptions: Critique and effectiveness evaluation,” *Data*, vol. 9, no. 8, pp. 1–19, 2024, doi: 10.3390/data9080095.

[45] N. R. Mishra, “Constructivist approach to learning: An analysis of pedagogical models of social constructivist learning theory,” *J. Res. Dev.*, vol. 6, no. 1, pp. 22–29, 2023, doi: 10.3126/jrdn.v6i01.55227.

[46] 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.

[47] A. Fatmawati, S. Zubaidah, S. Mahanal, and S. Sutopo, “Representation skills of students with different ability levels when learning using the lcmr model,” *Pegem Egit. ve Ogr. Derg.*, vol. 13, no. 1, pp. 177–192, 2022, doi: 10.47750/pegegog.13.01.20.

[48] W. J. D. Nascimento Júnior, C. Morais, and G. Girotto Júnior, “Enhancing AI responses in chemistry: Integrating text generation, image creation, and image interpretation through different levels of prompts,” *J. Chem. Educ.*, vol. 101, no. 9, pp. 3767–3779, Sep. 2024, doi: 10.1021/acs.jchemed.4c00230.

[49] R. A. Al-Kreimeen, “The effectiveness of the (jigsaw II) strategy in cooperative learning in developing thinking skills and cognitive assessment competencies among female students specializing in child education,” *J. Educ. Soc. Res.*, vol. 14, no. 3, pp. 306–323, 2024, doi: 10.36941/jesr-2024-0075.

[50] N. Idris, O. Talib, and F. Razali, “Strategies in mastering science process skills in science experiments: A systematic literature review,” *J. Pendidik. IPA Indones.*, vol. 11, no. 1, pp. 155–170, 2022, doi: 10.15294/jpii.v11i1.32969.

[51] A. Uzorka, O. Akiyode, and S. M. Isa, “Strategies for engaging students in sustainability initiatives and fostering a sense of ownership and responsibility towards sustainable development,” *Discov. Sustain.*, vol. 5, no. 1, pp. 1–12, 2024, doi: 10.1007/s43621-024-00505-x.

[52] A. D. Untari, “Game based learning: Alternative 21st century innovative learning models in improving student learning activeness,” *EDUEKSOS J. Pendidik. Sos. dan Ekon.*, vol. XI, no. 2, pp. 228–242, 2022, doi: 10.24235/edueksos. v11i2. 11919.