





APPLICATION OF THE NEW TOTW LEARNING MODEL TO IMPROVE THE CREATIVE THINKING ABILITY OF HIGH SCHOOL STUDENTS ON BUFFER SOLUTION MATERIALS

Haryanto¹, M. Dwi Wiwik Ernawati¹, Intan¹, Atri Widowati¹, Imam Kurniawan¹

¹ Universitas Jambi, Jambi, Indonesia

Corresponding author email: haryanto.fkip@unja.ac.id

Article Info

Received: Apr 12, 2025

Revised: May 29, 2025

Accepted: Jul 09, 2025

OnlineVersion: Jul 28, 2025

Abstract

This study aims to analyze the effect of the implementation of the Think, Observe, Talk, and Write (TOTW) learning model on students' creative thinking skills on buffer solution material. The method used is a quasi-experiment with a Non-Equivalent Control Group Design, involving two sample classes, namely the experimental class and the control class at Senior High School Islam Al-Falah, Jambi. The research instruments include essay tests and observation sheets covering aspects of sensitivity, fluency, flexibility, originality, and elaboration. Data were analyzed using statistical tests to test the hypothesis. The results showed that the implementation of the TOTW model significantly improved students' creative thinking skills, with the average posttest of the experimental class being higher than the control class. In addition, the observation results indicated an increase in creative thinking skills in the experimental class in all aspects assessed. Statistical tests showed a significant effect of the implementation of the TOTW model on students' creative thinking skills. This study concludes that the TOTW model is effective in improving students' creative thinking skills, especially on materials that require conceptual understanding such as buffer solutions. The implications of this study include recommendations for the implementation of innovative learning models in various learning contexts to support the development of students' high-level thinking skills.

Keywords Buffer Solution, Creative Thinking, Think Observe Talk Write



© 2025 by the author(s)

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

INTRODUCTION

Education in the 21st century demands a paradigm shift from conventional teaching to learning that equips students with essential competencies for the future (Adeoye et al., 2024; Chetry, 2024; Zaman, 2024). One of the most crucial skills is creative thinking, which enables individuals to generate new ideas, solve complex problems, and adapt to rapidly changing environments (Ramírez-Montoya et al., 2022; Adeoye & Jimoh, 2023; Poláková et al., 2023). The development of this ability cannot be separated from the learning process experienced in schools (Hayat et al., 2021; Mulang, 2021; Qureshi

et al., 2022). Therefore, the education system is challenged to design and implement learning experiences that actively stimulate and foster students' creative thinking potential.

However, the reality in the field often shows that the learning process is still dominated by a teacher-centered approach. This traditional method tends to position students as passive recipients of information, with a strong emphasis on memorizing concepts and formula (Nilimaa, 2023; Khoiriyah et al., 2024). This kind of environment is less conducive to developing higher-order thinking skills, including creative thinking (Kwangmuang et al., 2021; Lu et al., 2021; Chaojing, 2023). Students are rarely given the opportunity to explore, ask questions, discuss, or construct their own understanding, thus hampering their ability to think flexibly and innovatively.

This challenge is particularly evident in science subjects such as Chemistry, which often involve abstract concepts and complex calculations. Buffer solutions, for example, are one of the topics in high school chemistry that require a deep conceptual understanding, not just the ability to apply formulas (Laliyo et al., 2022; Oladejo et al., 2023; Rudi et al., 2023; Ula & Suyono, 2023). Students often struggle to understand the mechanism by which a buffer solution maintains pH (Salame et al., 2022; Santoso et al., 2024). An approach to learning that focuses solely on mathematical calculations fails to build a holistic and lasting understanding, limiting students' ability to creatively solve related problems in different contexts.

To address these issues, various innovative learning models have been developed to transform the learning environment into a more student-centered, active, and collaborative one (Dada et al., 2022; Zhao et al., 2022; Bhardwaj et al., 2025). These models are designed to go beyond mere knowledge transfer and instead focus on the process of knowledge construction by the students themselves. By actively involving students in the learning process, it is hoped that they can develop not only cognitive understanding but also essential skills such as critical thinking, communication, collaboration, and most importantly, creativity (Supena et al., 2021; Tohani & Aulia, 2022; Thornhill-Miller et al., 2023).

One promising innovative learning model is the Think, Observe, Talk, and Write (TOTW) model. This model is a structured learning sequence that guides students through four important stages of cognitive processing. The Think phase provides a moment for individual reflection and generating initial ideas (Yaacob et al., 2020; Guaman-Quintanilla et al., 2023). The Observe phase encourages students to gather information and data through observation or experimentation (Dada et al., 2022; Tong et al., 2022). The Talk phase facilitates collaborative discussions to share and refine ideas with their peers (Ruiz-Rojas et al., 2024; Zamiri & Esmaeili, 2024). Finally, the Write phase requires students to synthesize and articulate their understanding in a structured written form.

This study shows a significant difference in approach compared to previous studies by Panggabean et al., (2022) and Ayuningsih & Muna, (2023). Ayuningsih and Muna focused on the influence of the Discovery Learning model on critical thinking skills and student learning outcomes, with an emphasis on individual exploration oriented towards independent problem solving. Meanwhile, Panggabean et al. developed a Problem-Based Learning (PBL)-based learning module integrated with high-level thinking skills (HOTS), prioritizing structured learning to improve chemistry understanding in the classroom. Different from both, this study utilizes the TOTW (Think, Observe, Talk, Write) model which combines cognitive and collaborative stages to encourage students' creative thinking skills as a whole. The TOTW model stands out in facilitating student involvement at every stage of the learning process, with an approach that not only hones high-level thinking skills but also emphasizes the development of original ideas and communication skills. The gap in this research lies in its focus on the development of creative thinking skills, which is an essential element but has received less attention in previous studies, especially in the context of buffer solution material in high school.

The application of the TOTW model is very relevant to improve creative thinking skills in the context of buffer solution material. The structured stages allow students to build their understanding systematically. They can think about the initial pH of a solution, observe the effects of adding a small amount of acid or base, talk with their group to discuss why the pH change is minimal, and write a comprehensive explanation of the buffer mechanism. This process encourages them to connect theoretical concepts with empirical observations and express their unique understanding, which is the essence of creative thinking.

The novelty of this study lies in the specific application of the TOTW model to address conceptual difficulties in buffer solution material, an area that is often challenging, while explicitly targeting the enhancement of creative thinking skills. The urgency of this study is based on the urgent need to equip students with 21st century skills and provide alternative, proven learning models for

educators. Thus, this study not only fills a gap in the literature on chemistry pedagogy but also offers practical solutions to real problems in the classroom.

Therefore, this article will discuss in depth the implementation of the Think, Observe, Talk, and Write (TOTW) learning model as a strategic effort to improve the creative thinking skills of high school students, especially in learning buffer solution material. This discussion will cover the theoretical basis of the model, practical steps for implementing it in the classroom, and the potential impacts it can have in fostering a more meaningful and empowering learning experience for students.

RESEARCH METHOD

The method used in this study is experimental research using the Quasi Experiment form with a Non-Equivalent Control Group Design research design (Faizah & Nappu, 2025; Latifah & Purwantoyo, 2025). In this study there are two sample classes, namely the experimental class using the TOTW model and the control class not using the model. The design of this study is shown in the following table.

Table 1. Research Design

Group	Pretest	Treatment	Posttest
Experiment (TOTW model)	O ₁	X ₁	O ₂
Control	O ₃	X ₂	O ₄

The sample in this study was the population of students of class XI Natural Sciences of Al-Falah Islamic Senior High School Jambi totaling 72 people who were spread into three classes. The number of students in each class XI Mathematics Natural Sciences can be seen in the following table.

Table 2. Number of students in each class XI Mathematics Natural Sciences Al-Falah Islamic Senior High School Jambi

Class	Number of Students
XI Mathematics Natural Science 1	25 Students
XI Mathematics Natural Science 2	25 Students
XI Mathematics Natural Science 3	25 Students

The samples used were class XI Natural Sciences 1 and XI Natural Sciences 3 of Al-Falah Islamic Senior High School Jambi. The sample selection used the Random Sampling technique (Nanjundeswaraswamy & Divakar, 2021; Noor & Golzar, 2022). Class XI Natural Sciences 1 as the experimental class using the TOTW model while class XI Natural Sciences 3 as the control class using the TOTW Model.

The research procedure began with random sampling, where class XI Natural Science 1 was designated as the experimental class and class XI Natural Science 3 as the control class. In the initial stage, both classes were given an initial test (pretest) in the form of essay questions (O₁ and O₃) to measure their creative thinking skills before treatment. Furthermore, the experimental class (X₁) received learning about buffer solution material using the Think, Observe, Talk, and Write (TOTW) model, while the control class (X₂) used a conventional learning model. During this learning process, the researcher observed the creativity of students in both classes using observation sheets that included aspects of sensitivity, fluency, flexibility, originality, and elaboration. After the treatment period was over, both classes were given a final test (posttest) (O₂ and O₄) which was identical to the initial test to measure the increase in creative thinking skills. The data collected from the results of the pretest, posttest, and observation sheets were then analyzed to compare the effectiveness of the TOTW model with the conventional model in improving students' creative thinking skills. The research procedures can be seen in the following figure 1.



Figure 1. Research Procedures

Data collection was carried out using test and observation techniques. The instruments used were essay tests and observation sheets. In the study, creativity ability data was collected by adding up students' scores on the creativity observation sheet and essay test. There are five aspects as indicators of creativity used in this observation sheet, namely sensitivity, fluency, flexibility, originality, and elaboration. The outline of the essay test and the outline of the student creativity observation sheet and the student activity observation sheet can be seen in the table 3.

Table 3. Essay Test Grid Contents of the Essay Test Grid

Aspects of Creative Thinking	Question Indicator	Cognitive Domain	Number of Questions
Fluecy Orignity Elaboration sensitivity	The questions provide students with the opportunity to answer quickly and fluently and be able to produce ≥ 1 unique varied idea in explaining in detail about the acid-base properties of a salt solution	C4	2
	The questions provide students with the opportunity to answer quickly and fluently and be able to produce ≥ 1 unique varied idea in explaining in detail about the types of hydrolysis	C4	2
	The questions provide students with the opportunity to answer quickly and fluently and be able to produce ≥ 1 unique varied idea in explaining in detail about calculating the pH of a salt solution based on the acid-base composition	C4	2

Table 4. Grid of Student Creativity Observation Sheet

Aspects of Creative Thinking	Indikator	No Item
Sensitivity	Able to ask questions quickly and accurately	1
	Able to answer questions quickly and accurately	2
	Able to conclude problems quickly and accurately	3
Fluency	Able to express ideas, ideas in solving problems	4
	Able to produce varied ideas or ideas in solving problems	5
Flexibility	Able to present a concept in a different way	6
	Able to convey new ideas in solving problems	7
	Able to develop and enrich other people's ideas	8
Originality	Able to realize new ideas / ideas	9
	Able to spark ideas to solve problems and implement them	10

The analysis conducted can provide pretest and posttest before and after which aims to determine the increase in students' creativity abilities before and after learning. Student scores can be calculated using the following formula.

$$Presentation = \frac{\sum Score\ obtained}{Maximum\ score} \times 100\%$$

The analysis of the student creativity observation sheet was carried out by calculating the score results of each observation sheet containing 10 statements. The data was analyzed by adding up the scores of each statement item. The interpretation of the creativity observation sheet assessment scores is as follows.

$$Presentation = \frac{\sum \text{Observation result score}}{\text{Maximum score}} \times 100\%$$

The observation sheet assessment categories can be seen as follows.

Table 5. Categories of Student Creativity Observation Sheets

Value Scale	Score	Model implementation value	Category
4	> 32.7	> 81.75	Very Good
3	25.2 – 32.7	63.00 – 81.75	Good
2	17.6 – 25.1	44.00 – 62.75	Enough
1	10.0 – 17.5	25.00 – 43.75	Not Good

RESULTS AND DISCUSSION

This research was conducted at Al-Falah Islamic Senior High School in Jambi using two sample classes, namely the experimental class (11th grade of Natural Sciences 1) and the control class (11th grade of Natural Sciences 3) with 22 students in each class. The experimental class was given treatment using the TOTW model while the control class was given treatment using the TOTW Model. The following are the research results data starting from the essay test instrument, creative thinking observation sheets and observation sheets for the implementation of the model by teachers and students. The observation sheets used are supporting data that describe the situation of each class and the obstacles that arise during learning.

The essay test used consists of 6 questions given as a pretest and posttest. The pretest data obtained illustrates the initial abilities of students for both classes before studying the buffer solution material. Meanwhile, the posttest data is used as data in testing the research hypothesis. The following are the average pretest and posttest scores of students for the experimental and control classes.

Table 6. Average Pretest and Posttest Scores of Students

Class	Pretest Average	Posttest Average
Experiment	55.00	75.00
Control	51.50	65.00

Based on the average posttest score, it can be seen that the thinking ability of students in the experimental class is greater than the control class. The average score is 65.00 in the control class and 75.00 in the experimental class. The comparison of the average pretest and posttest scores of students in the experimental class and the control class is as follows. The cognitive value of students based on the aspect of creative thinking ability can be seen as table 7.

Table 7. Results of Students' Cognitive Assessment Based on Students' Creative Thinking Aspects

Aspects of Creative Thinking	No Question	Experimental Class		Control Class	
		Average	%	Average	%
Sensitivity	4	3.12	68	2.71	60
Fluency	1,2,4,5,6	13.25	72.5	11.94	65.3
Flexibility	1	1.72	37	1.53	33
Originality	3	2.12	47	2.18	46
Elaboration	3	2.08	46	2.12	47
Average		22.29	270.5	20.48	251.3
Amount		4.46	54.1	4.10	50.3

Based on the average results of each aspect of students' creative thinking in each class, it can be seen that the aspect with the highest percentage is the fluency aspect with a percentage of 72.5% for the experimental class and 65.3% for the control class. The aspect with the lowest percentage is the

flexibility aspect, which is 37% for the experimental class and 33% for the control class. The average number of students' cognitive assessment results from the five aspects of creative thinking abilities in the experimental class is higher than in the control class, which is 54.1% and 50.3%.

The results of the observation can be seen from the student learning process which is assessed at each meeting. The data from the observation of students' creative thinking skills in the experimental class are as follows table 8.

Table 8. Results of Students' Cognitive Assessment Based on Students' Creative Thinking Aspects

Meeting	Average	Category
1	56.80	Enough
2	67.45	Good
3	74.10	Good
Average	66.12	Good

Based on the results of observations of students' creative thinking abilities in the experimental class, there was an increase in each meeting. This can be seen from the average which is 56.80 in the fairly good category, 67.45 in the good category, and 74.10 in the good category. The data from the results of observations of students' creative thinking abilities in the control class can be seen in the following table.

Table 9. Results of Observations on Creative Thinking Abilities in the Control Class

Meeting	Average	Category
1	49.50	Enough
2	61.30	Good
3	66.40	Good
Average	59.07	Good

Based on the results of observations of students' creative thinking abilities in the control class, there was an average increase in each consecutive meeting, namely 49.50 with a fairly good category, 61.30 with a good category, and 66.40 with a good category. When compared to the total average of each class, it can be seen that the creative thinking abilities of students in the experimental class are greater than the control class, namely 66.12 with a good category and 59.07 with a good category.

If viewed from the average results of observations of students' creative thinking abilities based on their aspects in the experimental class and control class, it can be seen as follows. The average data on the results of observations of students' creative thinking abilities based on their aspects in the experimental class are as follows.

Table 10. Average Results of Observations of Students' Creative Thinking Abilities in the Experimental Class

No	Critical Thinking Aspects	Meeting			% Meeting 1	% Meeting 2	% Meeting 3	% %	Average
		1	2	3					
1	Sensitivity	2.14	2.36	2.59	51.89	58.71	71.21	60.61	2.42
2		1.82	2.09	2.55					
3		2.27	2.59	3.14					
	Average aspect	2.08	2.35	2.85					
4	Fluency	2.14	3.09	3.14	53.41	63.63	85.23	67.42	2.88
	Average aspect	2.14	3.09	3.14					
5	Flexibility	2.18	2.86	2.86	56.82	70.46	73.86	67.05	2.68
6		2.36	2.77	3.05					
	Average aspect	2.27	2.815	2.96					
7	Originality	1.91	2.68	3	53.03	61.36	70.08	61.49	2.46
8		2.27	2.5	2.77					
9		2.18	2.18	2.64					
	Average aspect	2.12	2.45	2.80					

No	Critical Thinking Aspects	Meeting			% Meeting 1	% Meeting 2	% Meeting 3	%	Average
		1	2	3					
10	Elaboration	2.18	2.55	2.55	54.55	63.64	63.64	60.61	2.43
	Average aspect	2.18	2.55	2.55					

Based on the average results of the observation sheet of students' creative thinking abilities in the experimental class, it can be seen that the percentage of the sensitivity aspect is 60.61%, fluency 67.42%, flexibility 67.05%, originality 61.49, and elaboration 60.61%. While in the control class, the average results of the observation sheet of students' creative thinking abilities can be seen as follows table 11.

Table 11. Average Results of Observations of Students' Creative Thinking Abilities Based on Aspects in the Control Class

No	Critical Thinking Aspects	Meeting			% Meeting 1	% Meeting 2	% Meeting 3	%	Average
		1	2	3					
1		1.59	2.18	2.59					
2	Sensitivity	1.5	2.14	2.45	41.67	55.2	67.8	54.92	2.20
3		1.91	2.32	3.09					
	Average aspect	1.67	2.21	2.71					
4	Fluency	2.09	2.82	2.73	52.27	70.45	68.18	63.63	2.55
	Average aspect	2.09	2.82	2.73					
5	Flexibility	1.95	2.23	2.5	50.57	57.39	69.32	59.09	2.36
6		2.09	2.36	3.05					
	Average aspect	2.02	2.30	2.78					
7	Originality	1.82	2.41	2.05	47.73	59.47	57.2	54.80	2.20
8		2	2.5	2.5					
9	Average aspect	1.92	2.38	2.29					
10	Elaboration	1.95	2.32	2.27	46.59	57.95	56.82	53.79	2.18
	Average aspect	1.95	2.32	2.27					

Based on the average results of the observation sheet of creative thinking ability of control class students, the percentage obtained for each aspect of sensitivity was 54.92%, fluency 63.64%, flexibility 59.09%, originality 54.80%, and elaboration 53.79%. The comparative depiction of the results of students' creative thinking ability in each aspect in the experimental class and the control class based on the observation sheet can be seen as follows.

The hypothesis in this study is that there is a significant influence in the use of the TOTW model on students' creative thinking skills in the buffer solution material, so to test the hypothesis, the t-test is used on the condition that the data obtained are normally distributed and homogeneous.

Table 12. Normality Test Results

No.	Data analyzed	$L_{Count} (L_0)$	$L_{Table} (\alpha = 0.05)$	Description
1.	Experimental class posttest results	0.18799	0.180	$L_{count} < L_{table}$ (Normal Data)
2.	Control class posttest results	0.17227	0.180	$L_{count} < L_{table}$ (Normal Data)

Homogeneity test is conducted to determine whether the data variance is homogeneous or not. The homogeneity test used in this study is the Fisher test. The results of the homogeneity test of the essay test data that have been obtained with $F_{count} < F_{table}$ are $1.0649 < 2.0841$. So it can be concluded that the data is homogeneous.

The t-test used is the right-hand test. The results of the hypothesis t-test calculation are as follows table 13.

Table 13. T-Test Results

No.	Data analyzed	T _{Count}	L _{Table} ($\alpha = 0.05$)	Description
1.	Pretest results of essay test	1.0649	2.0841	T _{count} < t _{table} there is no influence
2.	Posttest results of essay test	1.7697	1.6819	T _{count} > t _{table} there is influence

The results of the t-test obtained with $t_{count} > t_{table}$ are 1.7697 1.6819. So it can be concluded that there is a significant influence in the use of the TOTW model on students' creative thinking skills on the material of buffer solutions. The application of innovative learning methods such as the TOTW model in this study proves the importance of an approach that emphasizes student interactivity and creativity. This method does not only teach material, but also trains students to develop critical and creative thinking skills. In the context of modern education, this kind of approach is relevant to prepare students to face real-world challenges, where creative problem solving and adaptation to change are the keys to success (Gale et al., 2022; Nilimaa, 2023).

Teachers play an important role in the success of learning models such as TOTW. The success of implementing this model is highly dependent on the teacher's ability to facilitate a learning process that actively involves students (Dewi, 2022; Rohmi & Wahyuni, 2024). Teachers need to create a conducive environment so that students feel comfortable exploring, expressing ideas, and working together with classmates (Saleem et al., 2021; Saroyan, 2021). In this study, the success of implementing this model can be an inspiration for other teachers to continue to develop their competence in using learning methods that are oriented towards developing student potential.

One of the advantages of the TOTW model is its ability to develop students' cognitive and non-cognitive aspects simultaneously. In addition to improving creative thinking skills, this method also trains students' communication, cooperation, and emotional management skills (Barevičiūtė et al., 2023; Stanikzai, 2023). The interactions that occur during the learning process allow students to learn from each other, creating a more lively classroom dynamic (Li & Xue, 2023; Mustoip et al., 2024). Thus, this model not only improves academic achievement but also shapes students' character to become lifelong learners. Although the TOTW model shows promising results, its implementation is not free from challenges. Constraints such as time constraints, student readiness, and teacher skills in implementing this model are issues that need to be considered (Silva et al., 2021; Zou et al., 2021).

Therefore, further training is needed for teachers to master this method optimally. In addition, the development of relevant and interesting teaching materials is also a supporting factor for the success of this model. By overcoming these challenges, the TOTW model has the potential to be applied more widely in various learning contexts.

The results of this study provide important implications for education policy makers to encourage the use of innovative learning methods. The curriculum must be designed in such a way that it provides space for the application of models that are oriented towards the development of high-level thinking skills. In addition, investment in teacher training, provision of supporting resources, and integration of technology in learning can further strengthen the effectiveness of these methods. Thus, education can be transformed to be more relevant, responsive, and adaptive to the needs of students and future society.

CONCLUSION

Based on the results of the research and discussion that have been carried out, the research conclusion is that the application of the TOTW model can significantly influence students' creative thinking skills on the material on buffer solutions in grade XI of Senior High School. This study makes a significant contribution in demonstrating the effectiveness of the TOTW model in improving students' creative thinking skills, but there are some limitations that need to be considered. One limitation is the scope of the study which only covers one school with a limited number of samples, so the results may be less generalizable to a wider population. In addition, this study only focuses on the material of buffer solutions, while the application of the TOTW model to other chemistry topics or different subjects has not been explored. For further research, it is recommended that this model be applied to various subjects and different levels of education to test the consistency of its effectiveness. Further research can also explore the integration of technology in the TOTW model to create a more dynamic learning

environment, as well as considering other variables such as student motivation and individual learning styles to provide more comprehensive insights.

ACKNOWLEDGMENTS

We would like to thank all parties who have supported and helped carry out this research. Our sincere gratitude goes to the educational institutions, teachers, and students who have participated, as well as parties who have provided facilities and technical support during the research. Hopefully the results of this research can provide a positive contribution to the development of the world of education.

AUTHOR CONTRIBUTIONS

Conceptualization, Haryanto and M. Dwi Wiwik Ernawati; Methodology and Investigation, Haryanto, Imam Kurniawan, Atri Widowati; Software, Resources, and Data Curation, Intan; Validation, Formal Analysis, and Supervision, M. Dwi Wiwik Ernawati; Writing – Original Draft Preparation, Haryanto; Writing – Review & Editing, M. Dwi Wiwik Ernawati; Visualization, Intan; Project Administration, Haryanto; Funding Acquisition, M. Dwi Wiwik Ernawati.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

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.

REFERENCES

- Adeoye, M. A., & Jimoh, H. A. (2023). Problem-Solving Skills Among 21st-Century Learners Toward Creativity and Innovation Ideas. *Thinking Skills and Creativity Journal*, 6(1), 52–58. <https://doi.org/10.23887/tscj.v6i1.62708>
- Adeoye, M. A., Prastikawati, E. F., & Abimbowo, Y. O. (2024). Empowering Learning: Pedagogical Strategies for Advancing 21st Century Skills and Quality Education. *Journal of Nonformal Education*, 10(1), 10–21.
- Ayuningsih, S., & Muna, L. N. (2023). Influence of the Discovery Learning Learning Model on Critical Thinking Abilities and Student Learning Outcomes in Buffer Solution Material. *Jurnal Penelitian Pendidikan IPA*, 9(11), 9438–9446. <https://doi.org/10.29303/jppipa.v9i11.4469>
- Barevičiūtė, J., Dadelo, S., & Asakavičiūtė, V. (2023). The Skills of Critical Thinking, Creativity, and Communication as Tools for Overcoming Social Simulation in the Context of Sustainability: A Case Study of Students' Self-Assessment of the Affective Domain of Learning. *Sustainability (Switzerland)*, 15(14). <https://doi.org/10.3390/su151410935>
- Bhardwaj, V., Zhang, S., Tan, Y. Q., & Pandey, V. (2025). Redefining learning: student-centered strategies for academic and personal growth. *Frontiers in Education*, 10(February), 1–15. <https://doi.org/10.3389/educ.2025.1518602>
- Chaojing, M. (2023). A Study on Strategies for Cultivating Higher-Order Thinking Skills in Primary and Secondary School Students. *Frontiers in Educational Research*, 6(20), 67–71. <https://doi.org/10.25236/fer.2023.062011>
- Chetry, K. K. (2024). Transforming Education: Paradigm Shifts in 21st Century Learning. *International Journal of Multidisciplinary Research*, 2(5), 469–479.
- Dada, D., Laseinde, O. T., & Tartibu, L. (2022). Student-Centered Learning Tool for Cognitive Enhancement in the Learning Environment. *Procedia Computer Science*, 217, 507–512. <https://doi.org/10.1016/j.procs.2022.12.246>
- Dewi, F. S. (2022). The Role of Teachers in Implementing an Independent Learning System for Lower Grade Students. *Jurnal Ilmiah Sekolah Dasar*, 6(2), 220–227. <https://doi.org/10.23887/jisd.v6i2.44572>
- Faizah, N., & Nappu, S. (2025). The Use of Flower Writing Strategy on Students' Writing Skills (A Quasi-Experimental Research Design at the Tenth-Grade of SMA Negeri 9 Gowa). *PROJECT (Professional Journal of English Education)*, 8(3), 662–670.

- Gale, A. P., Chapman, J. O., White, D. E., Ahluwalia, P., Williamson, A. K. J., Peacock, K. R., Akagbosu, R., Lepine, T. M., Arizor, I., Bone, L. A., Brown, J., Fahrngruber, A. M., Goldberg-Flood, A., Kovirineni, S., Lamb-Laurin, S. J., Zia, N., Innocent, S., Lee, W., Moran, G., ... Cooke, S. J. (2022). On embracing the concept of becoming environmental problem solvers: the trainee perspective on key elements of success, essential skills, and mindset. *Environmental Reviews*, 30(1), 1–9. <https://doi.org/10.1139/er-2021-0040>
- Guaman-Quintanilla, S., Everaert, P., Chiluiza, K., & Valcke, M. (2023). Impact of design thinking in higher education: a multi-actor perspective on problem solving and creativity. *International Journal of Technology and Design Education*, 33(1), 217–240. <https://doi.org/10.1007/s10798-021-09724-z>
- Hayat, A. A., Keshavarzi, M. H., Zare, S., Bazrafcan, L., Rezaee, R., Faghihi, S. A., Amini, M., & Kojuri, J. (2021). Challenges and opportunities from the COVID-19 pandemic in medical education: a qualitative study. *BMC Medical Education*, 21(1), 1–13. <https://doi.org/10.1186/s12909-021-02682-z>
- Khoiriyah, S., Wiliyanti, V., Gunawan, I., Negeri Raden Intan Lampung, I., Letkol Endro Suratmin, J., & Lampung, B. (2024). The Influence of The STEM Learning Approach on Students Communication and Collaboration Abilities on Elasticity Materials. *Jurnal Penelitian Pembelajaran Fisika*, 15(3), 263–271. <https://doi.org/10.26877/jp2f.v15i3.18724>
- Kwangmuang, P., Jarutkamolpong, S., Sangboonraung, W., & Daungtod, S. (2021). The development of learning innovation to enhance higher order thinking skills for students in Thailand junior high schools. *Heliyon*, 7(6), e07309. <https://doi.org/10.1016/j.heliyon.2021.e07309>
- Laliyo, L. A. R., Sumintono, B., & Panigoro, C. (2022). Measuring changes in hydrolysis concept of students taught by inquiry model: stacking and racking analysis techniques in Rasch model. *Heliyon*, 8(3), e09126. <https://doi.org/10.1016/j.heliyon.2022.e09126>
- Latifah, A., & Purwantoyo, E. (2025). The Effectiveness of the Example Non Example Learning Model assisted by Nearpod Media to Improve the Analysis and Communication Skills of Reproductive System Material. *Journal of Biology Education*, 14(1), 27–33.
- Li, J., & Xue, E. (2023). Dynamic Interaction between Student Learning Behaviour and Learning Environment: Meta-Analysis of Student Engagement and Its Influencing Factors. *Behavioral Sciences*, 13(1). <https://doi.org/10.3390/bs13010059>
- Lu, K., Yang, H. H., Shi, Y., & Wang, X. (2021). Examining the key influencing factors on college students' higher-order thinking skills in the smart classroom environment. *International Journal of Educational Technology in Higher Education*, 18(1), 1–13. <https://doi.org/10.1186/s41239-020-00238-7>
- Mulang, H. (2021). The Effect of Competences, Work Motivation, Learning Environment on Human Resource Performance. *Golden Ratio of Human Resource Management*, 1(2), 84–93. <https://doi.org/10.52970/grhrm.v1i2.52>
- Mustoip, S., Lestari, D., & Purwati, R. (2024). Implementation of STEAM Learning Methods to Develop Collaborative and Creative Characters of Elementary School Students. *Journal of Primary School ISSN:*, 1(2), 14–20.
- Nanjundeswaraswamy, T. S., & Divakar, S. (2021). Determination of Sample Size and Sampling Methods in Applied Research. *Proceedings on Engineering Sciences*, 3(1), 25–32. <https://doi.org/10.24874/pes03.01.003>
- Nilimaa, J. (2023). New Examination Approach for Real-World Creativity and Problem-Solving Skills in Mathematics. *Trends in Higher Education*, 2(3), 477–495. <https://doi.org/10.3390/higheredu2030028>
- Noor, S., & Golzar, J. (2022). Simple Random Sampling. *International Journal of Education and Language Studies*, 1(2), 78–82. [https://doi.org/10.1016/S0169-7161\(88\)06006-7](https://doi.org/10.1016/S0169-7161(88)06006-7)
- Oladejo, A. I., Ademola, I. A., Ayanwale, M. A., & Tobih, D. (2023). Concept Difficulty In Secondary School Chemistry – An Intra-Play Of Gender, School Location And School Type. *Journal of Technology and Science Education*, 13(1), 255–275. <http://www.jotse.org/index.php/jotse/article/view/110/142>
- Panggabean, F. T. M., Sari Munthe, G. W., Silitonga, P. M., Juniar, A., & Selly, R. (2022). Development of HOTS Integrated Problem Based Learning (PBL) Chemistry Learning Module on Buffer Solution Material at SMA Negeri 1 Purba. *International Journal of Computer Applications Technology and Research*, 11(08), 301–304.

- <https://doi.org/10.7753/ijcatr1108.1001>
- Poláková, M., Suleimanová, J. H., Madzík, P., Copuš, L., Molnárová, I., & Polednová, J. (2023). Soft skills and their importance in the labour market under the conditions of Industry 5.0. *Heliyon*, 9(8), 1–20. <https://doi.org/10.1016/j.heliyon.2023.e18670>
- Qureshi, M., Mahdiyyah, D., Mohamed, Y., & Ardchir, M. (2022). Scale For Measuring Arabic Speaking Skills In Early Children’s Education. *Journal International of Lingua and Technology*, 1(2), 114–130. <https://doi.org/10.55849/jiltech.v1i2.81>
- Ramírez-Montoya, M. S., Castillo-Martínez, I. M., Sanabria-Z, J., & Miranda, J. (2022). Complex Thinking in the Framework of Education 4.0 and Open Innovation—A Systematic Literature Review. *Journal of Open Innovation: Technology, Market, and Complexity*, 8(1), 1–15. <https://doi.org/10.3390/joitmc8010004>
- Rohmi, F., & Wahyuni, S. (2024). English Teacher’s Strategy in Teaching Writing Using Discovery Learning. *Jurnal Pendidikan Bahasa Inggris Undiksha*, 11(2), 122–128. <https://doi.org/10.23887/jpbi.v11i2.50812>
- Rudi, L., Haetami, A., Asria, A., & Naqib bin Shuid, A. (2023). Analysis of Chemistry Problem-Solving Ability in Symbolic Level for Senior High School Students. *Jurnal Pendidikan Progresif*, 13(1), 133–150. <https://doi.org/10.23960/jpp.v13.i1.202310>
- Ruiz-Rojas, L. I., Salvador-Ullauri, L., & Acosta-Vargas, P. (2024). Collaborative Working and Critical Thinking: Adoption of Generative Artificial Intelligence Tools in Higher Education. *Sustainability (Switzerland)*, 16(13). <https://doi.org/10.3390/su16135367>
- Salame, I. I., Ramirez, L., Nikolic, D., & Krauss, D. (2022). Investigating students difficulties and approaches to solving buffer related problems. *International Journal of Instruction*, 15(1), 911–926. <https://doi.org/10.29333/iji.2022.15152a>
- Saleem, A., Kausar, H., & Deeba, F. (2021). Social Constructivism: A New Paradigm in Teaching and Learning Environment. *Perennial Journal of History*, 2(2), 403–421. <https://doi.org/10.52700/pjh.v2i2.86>
- Santoso, T., Ahmar, D. S., Tukaedja, S. V., & Haetami, A. (2024). The Effect of the Discovery Learning Model with a Scientific Approach on Student Representation Ability in the Buffer Solution. *Jurnal Penelitian Pendidikan IPA*, 10(6), 3296–3302. <https://doi.org/10.29303/jppipa.v10i6.7389>
- Saroyan, J. S. (2021). Developing a supportive peer environment: Engaging students through cooperative skills in the classroom. *Advances in Developmental and Educational Psychology*, 3(1), 81–89. <https://doi.org/10.25082/adep.2021.01.001>
- Silva, R., Farias, C., & Mesquita, I. (2021). Challenges faced by preservice and novice teachers in implementing student-centred models: A systematic review. *European Physical Education Review*, 27(4), 798–816. <https://doi.org/10.1177/13563336X21995216>
- Stanikzai, M. I. (2023). Critical Thinking, Collaboration, Creativity and Communication Skills among School Students: A Review Paper. *European Journal of Theoretical and Applied Sciences*, 1(5), 441–453. [https://doi.org/10.59324/ejtas.2023.1\(5\).34](https://doi.org/10.59324/ejtas.2023.1(5).34)
- Supena, I., Darmuki, A., & Hariyadi, A. (2021). The influence of 4C (constructive, critical, creativity, collaborative) learning model on students’ learning outcomes. *International Journal of Instruction*, 14(3), 873–892. <https://doi.org/10.29333/iji.2021.14351a>
- Thornhill-Miller, B., Camarda, A., Mercier, M., Burkhardt, J. M., Morisseau, T., Bourgeois-Bougrine, S., Vinchon, F., El Hayek, S., Augereau-Landais, M., Mourey, F., Feybesse, C., Sundquist, D., & Lubart, T. (2023). Creativity, Critical Thinking, Communication, and Collaboration: Assessment, Certification, and Promotion of 21st Century Skills for the Future of Work and Education. *Journal of Intelligence*, 11(3). <https://doi.org/10.3390/jintelligence11030054>
- Tohani, E., & Aulia, I. (2022). Effects of 21st Century Learning on the Development of Critical Thinking, Creativity, Communication, and Collaboration Skills. *Journal of Nonformal Education*, 8(1), 46–53. <https://journal.unnes.ac.id/nju/index.php/jne>
- Tong, D. H., Uyen, B. P., & Ngan, L. K. (2022). The effectiveness of blended learning on students’ academic achievement, self-study skills and learning attitudes: A quasi-experiment study in teaching the conventions for coordinates in the plane. *Heliyon*, 8(12), e12657. <https://doi.org/10.1016/j.heliyon.2022.e12657>
- Ula, F. R., & Suyono. (2023). Development of Argumentation Skills Assessment Instruments on Buffer Solution Material. *Jurnal Penelitian Pendidikan IPA*, 9(12), 10792–10799.

- <https://doi.org/10.29303/jppipa.v9i12.4760>
- Yaacob, A., Mohd Asraf, R., Hussain, R. M. R., & Ismail, S. N. (2020). Empowering Learners' Reflective Thinking through Collaborative Reflective Learning. *International Journal of Instruction*, 14(1), 709–726. <https://doi.org/10.29333/IJI.2021.14143A>
- Zaman, F. U. (2024). Revolutionizing Teacher Preparation: A Holistic Framework for Equipping Future Educators with 21st Century Skills and Innovative Practices. *Hamdard Educus*, 3(1), 17–29.
- Zamiri, M., & Esmaceli, A. (2024). Methods and Technologies for Supporting Knowledge Sharing within Learning Communities: A Systematic Literature Review. *Administrative Sciences*, 14(1), 1–34. <https://doi.org/10.3390/admsci14010017>
- Zhao, E., He, J., Jin, Z., & Wang, Y. (2022). Student-Centered Learning Environment Based on Multimedia Big Data Analysis. *Mobile Information Systems*, 2022. <https://doi.org/10.1155/2022/9572413>
- Zou, C., Li, P., & Jin, L. (2021). Online college English education in Wuhan against the COVID-19 pandemic: Student and teacher readiness, challenges and implications. *PLoS ONE*, 16(10 October), 1–24. <https://doi.org/10.1371/journal.pone.0258137>