JPPIPA 11(8) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Implementation of Wordwall Media with a STEM Approach to Increase Student Creativity and Learning Outcomes in Chemical Compound Nomenclature

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Received: May 25, 2025
Revised: July 03, 2025
Accepted: August 25, 2025
Published: August 31, 2025

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DOI: 10.29303/jppipa.v11i8.11987

Abstract: This study aimed to examine the effect of integrating Wordwall media with the STEM approach on student creativity and learning outcomes in chemical compound nomenclature. A quasi-experimental method with a Pretest-Posttest Control Group design was applied. The experimental group used STEM-based Wordwall media, while the control group received conventional teaching. Results showed that the experimental group achieved a moderate N-Gain (0.66) compared to the control group's lower N-Gain (0.29). The Mann-Whitney test indicated a significant difference between the groups ($p < 0.05$), suggesting that STEM-based Wordwall media improved learning outcomes. Creativity, measured using a Torrance-based questionnaire, also showed significant improvement after the intervention. In conclusion, integrating Wordwall media with the STEM approach effectively enhances student creativity and learning outcomes in chemical compound nomenclature.

Keywords: Creativity; Learning outcomes; STEM; Wordwall

Introduction

The complexity of 21st-century learning demands educational innovations that can develop students' creativity, critical thinking, and problem-solving skills (Voogt et al., 2012). In chemistry education, particularly in the topic of chemical compound nomenclature, students often encounter difficulties due to the abstract and complex nature of the concepts involved (Siburian et al., 2025). Other studies have also highlighted that chemistry concepts encompass macroscopic, submicroscopic, and symbolic levels, thus requiring concrete approaches to prevent misconceptions (Sandi-Urena et al., 2020). Furthermore, major learning difficulties in chemistry frequently arise from a lack of visualization and contextual learning methods (Iswara et al., 2021; Prayunisa, 2022). Conventional teaching methods have proven to be ineffective in addressing the challenges in learning chemical nomenclature, as indicated by students' low mastery and conceptual understanding in the topics of chemical nomenclature (Asiyah, 2022; Deleña & Marasigan, 2023). Therefore, there is a need for interactive, student-centered learning approaches to enhance both conceptual understanding and creativity (Aditya & Pusposari, 2024; Aytaç & Kula, 2020). In line with this, the application of teaching methods that integrate technology and contextual approaches becomes increasingly important in enhancing the quality of learning, especially for topics with high levels of complexity, such as chemical compound nomenclature (Johnson et al., 2020).

Integrating digital learning media such as Wordwall with the STEM approach shows significant potential as an innovative solution to improve learning quality (Azizah et al., 2024; Fauziyati, 2023). However, research specifically exploring the integration of Wordwall media with the STEM approach in teaching chemical compound nomenclature remains very

How to Cite:
Sandra, M. A., Adhim, F., & Gita, R. S. D. (2025). Implementation of Wordwall Media with a STEM Approach to Increase Student Creativity and Learning Outcomes in Chemical Compound Nomenclature. *Jurnal Penelitian Pendidikan IPA*, *11*(8), 751–759. https://doi.org/10.29303/jppipa.v11i8.11987

limited. Most existing studies on Wordwall focus solely on its effectiveness in improving learning outcomes or higher-order thinking skills without combining it with STEM models (Kusumaningtyas & Yuniawatika, 2024; Natasha et al., 2024; Paulus et al., 2023). Conversely, STEM-based learning research in chemistry generally targets topics such as chemical equilibrium (Gurusinga & Eddiyanto, 2025) or electrolyte and nonelectrolyte solutions (Gusman et al., 2023; Rahmawati et al., 2019) rather than chemical nomenclature. Nevertheless, STEM-based learning has been proven effective in enhancing conceptual understanding, learning outcomes, and students' critical thinking skills in science and chemistry (Nurfaijah et al., 2021; Sinta et al., 2021; Yreck, 2024).

This research is novel as it integrates Wordwall media with the STEM learning model specifically for the topic of chemical compound nomenclature to simultaneously improve students' creativity and conceptual understanding. This integration is essential as it provides an effective pedagogical strategy to address abstract conceptual difficulties while fostering higher-order thinking skills necessary to face future scientific challenges (English, 2016; Voogt & Roblin, 2022). Therefore, this study aims to investigate the effectiveness of STEM-integrated Wordwall media in enhancing students' creativity and learning outcomes in chemical compound nomenclatur

Method

Type of Research

This study employs a quantitative approach aimed at assessing the effectiveness of integrating Wordwall media with the STEM approach to improve students' creativity and learning outcomes on chemical compound nomenclature. Data collected is in numerical form, allowing for statistical analysis. Learning outcomes are measured using pre-test and post-test assessments, while creativity is evaluated through a questionnaire based on Torrance's creativity dimensions. The results will be analyzed to determine the contribution of STEM-based Wordwall media in enhancing students' creativity and conceptual understanding.

Research Design

The research applies a quasi-experimental design involving two groups: an experimental group and a control group, each given pre-test and post-test. The experimental group receives instruction using STEM-based Wordwall media, while the control group engages in conventional learning using standard materials provided by the school. Prior to the intervention, both groups complete a pre-test to assess initial understanding and creativity levels. After the intervention, a post-test is administered to evaluate learning outcomes. The differences between pre-test and post-test scores are analyzed to assess the effect of the intervention.

Population and Sample

The population consists of 10th-grade students from SMA Negeri Senduro, Lumajang, which includes seven parallel classes. Two classes—X-1 and X-2—were selected as samples, each comprising 30 students. The sampling technique used is purposive sampling, based on the similarity of teaching schedules, subject teachers, and prior academic performance, which ensures a baseline level of comparability. Class X-1 serves as the control group and receives conventional instruction, while Class X-2 is treated as the experimental group with STEM-based Wordwall learning. This selection ensures comparable characteristics between groups and strengthens the validity of the findings.

Research Instruments

The instruments used in this research are based on theoretical foundations and validated by prior studies. All instruments underwent validity and reliability testing to ensure accurate and consistent measurement.

Learning Outcome Test

This instrument measures students' understanding of chemical compound nomenclature.

a) Question type: 14 multiple-choice questions (five options), designed to assess Bloom's cognitive levels C3–C6.
b) Development: Questions are constructed based on the Merdeka Curriculum.
c) Testing: Validity is established through expert review, and reliability is tested using Cronbach's Alpha.
d) Scoring: Data from the post-test is analyzed using the normalized gain (N-gain) score to determine improvement.

Student Creativity Questionnaire

This instrument uses a 5-point Likert scale (from Strongly Disagree to Strongly Agree) to assess creativity dimensions after the intervention. The questionnaire is adapted from Torrance's framework (Torrance, 2012) and tailored for learning contexts involving STEM and interactive media (Sugiyono, 2017).

Experiment Implementation

The research process is conducted in three phases:

Preparation Phase

Learning materials and tools are developed, including a STEM-integrated lesson plan and Wordwall-based modules tailored to the experimental group.

Implementation Phase

The experimental group undergoes instruction with STEM-based Wordwall activities, while the control group is taught using conventional methods and standard school worksheets (LKPD provided by the school, not developed by the researcher).

Evaluation Phase

Both groups complete the post-test and creativity questionnaire. Results are compared and analyzed to assess the impact of the intervention on students' learning outcomes and creativity.

Table 1. Learning Syntax for Experimental and Control Groups

Learning Stage based	Experiment Group (STEM-Wordwall Media)	Control Group (Conventional Learning)
Student Orientation to the Problem	The teacher shows food packaging containing chemical substances such as baking soda and introduces the names of the chemical compounds in the composition. Practical synthesis of sodium acetate from CH3COOH and NaHCO3.	The teacher explains that chemical compounds are widely used in daily life, for example in the food, medicine and cosmetics industries.
Learning organization	The teacher divides students into heterogeneous groups and explains the learning model that will be carried out.	The teacher divides students into heterogeneous groups and distributes LKPD to be discussed together the group
Guiding Individual and Group Inquiry	Students conduct simple experiments to observe changes in mass (stoichiometry) and the law of conservation of mass. Identify the molecular formulas and names of the compounds involved in the sodium acetate synthesis reaction and find the rules of naming ionic and covalent compounds through literature study	Present the material of chemical compound names using the lecture method and LKPD which is done in groups
Developing and Presenting Results	Process the information on chemical compound nomenclature material obtained from the discussion results and present the findings in front of the class	Each group takes turns to present the results of their group discussion
Analyzing and Evaluating	The teacher provides chemical nomenclature exercises based on Wordwall as a digital evaluation	Giving written quizzes to evaluate students' understanding
Problem-Solving Process	Students reflect on their understanding and the application of concepts in real life	
Summarized	Students, together with the teacher, conclude the results of the discussion	Students, together with the teacher, conclude the results of the discussion
Reflection and Closing	The teacher facilitates students in reviewing the learning that has been implemented.	Reflection was conducted verbally, and feedback was provided through manual assessment

Data Analysis

The data analysis process in the study is as follows:

Data Collection

The data collected in this study included two main variables, namely creativity and student learning outcomes, using the following instruments:

Learning Outcome Data

a) Pretest and Posttest

Used to assess students' understanding levels before and after participating in the learning process.

b) N-gain Score

Used to measure learning gains by comparing pretest and posttest scores (Hake, 1999).

$$N - Gain = \frac{\text{Skor post test} - \text{Skor pre test}}{\text{Skor maksimal} - \text{Skor pre test}} \quad (1)$$

Table 2. Criteria for N-gain Results

Criteria N-gain	Category Improved	Interpretation of Improvement
g ≥ 0.70	High	Significant improvement
0.30 ≤ g< 0.70	Medium	Moderate increase
g < 0.30	Low	Minimum improvement

Student Creativity Data

The questionnaire was developed based on four creativity indicators proposed by Torrance, namely fluency, flexibility, originality, and elaboration. These indicators were measured using a Likert scale (Li et al., 2025). The questionnaire was administered to students before and after the learning process to evaluate changes in their creativity levels related to the material being taught.

Data Analysis Technique

The data analysis techniques used in this study include the following:

a) Descriptive statistical analysis, which was used to identify general trends in student learning outcomes and creativity. The parameters used in this analysis include the average value (mean).

$$\bar{x} = \frac{\Sigma x}{n} \tag{2}$$

Standard deviation

$$S= \frac{\sqrt{\Sigma(x_i-\bar{x})^2}}{n-1} \tag{3}$$

Minimum and maximum values
Question distribution

b) Inferential statistical analysis

The normality test aims to determine whether the distribution of data obtained follows a normal pattern. The test used for this test is Shapiro- Wilk or Kolmogorov-Smirnov.

Table 3. Normality Test Criteria

Limitations	Category
p > 0.05	data is normally distributed
p ≤ 0.05	data is not normally distributed

Paired Sample t-test test used to test whether there is a significant difference between pretest and posttest scores (learning outcomes and creativity).

Table 4. Decision-Making Criteria

Limitations	Category
p (2-tailed)< 0.05	there is a significant difference
p ≥ 0.05	there is no significant difference

If the data is not normally distributed, the Wilcoxon Signed Rank Test is used. This test is used as a non-parametric alternative to the t-test. Criteria: If p < 0.05, then there is a significant difference.
Validity and reliability test of creativity questionnaire

Item Validity Test (Pearson Product Moment)
Pearson correlation formula:

$$r = \frac{n\sum XY-(\sum X)(\sum Y)}{\sqrt{[n\sum X^2-(\sum X)^2][n\sum Y^2-(\sum Y)^2]}} \tag{4}$$

Description:
r count: the result of the Pearson correlation calculation between the item score and the total score.
r table: the r value from the Pearson distribution table based on free degrees (df = n - 2) and a certain level of significance (for example 0.05). Valid if r count ≥ $r\ table$, otherwise Invalid (Sugiyono, 2017).

Table 5. Criteria for Instrument Item Validity (Pearson Product Moment Correlation Test)

Item	r count	r table (df= n-2)	Status
1	0.45	0.361	Valid
2	0.30	0.361	Invalid
3	0.55	0.361	Valid
...	...	...	...

Reliability Test (Cronbach's Alpha)

$$\alpha = \frac{k}{k-1}\left(1-\frac{\sum\sigma_i^2}{\sigma_t^2}\right)\ldots \tag{5}$$

Description:
k = number of instrument items
σ_i^2= variance of each item
σ_t^2= total variance

Table 6. Instrument Reliability Criteria

Value Range α	Reliability Category
α ≥ 0.90	Very reliable
0.70 ≤ α < 0.90	Moderately reliable
0.60 ≤ α < 0.70	Acceptable
α < 0.60	Less reliable

Result and Discussion

Learning Outcome Results

This study was conducted from April 7 to 28, 2025, at SMA Negeri Senduro and focused on the topic of chemical compound nomenclature. The main objective was to examine the impact of using Wordwall media integrated with a STEM approach on students' learning outcomes and creativity. Two parallel classes participated in this study: Class X-2 as the experimental group and Class X-1 as the control group.

Students' understanding was measured through pre-test and post-test assessments consisting of multiple-choice items. The improvement in student learning outcomes was analyzed using the N-Gain formula (Hake, 1999) as described in the method section.

Table 7. N-Gain Comparison of Experimental and Control Classes

Group	N-gain average	N-gain category	Interpretation
Experiment Class (X2)	0.70 - 0.83	High	Wordwall with STEM significantly improves student learning outcomes
Control Class (X1)	0.23 - 0.36	Low - Medium	Conventional methods result

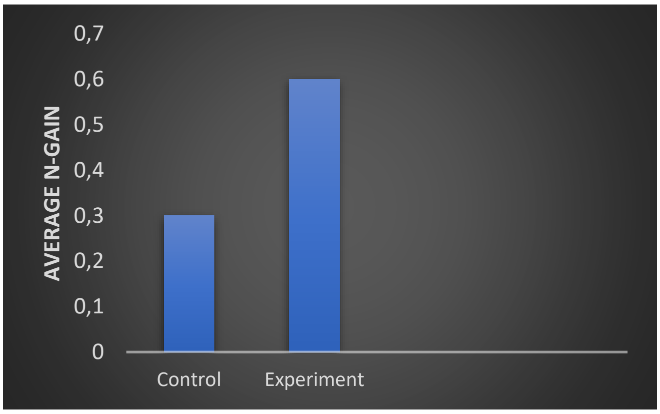

Figure 1. N-gain comparison of experimental and control classes

The experimental class showed a substantial increase in learning outcomes, with most N-Gain scores categorized as high. In contrast, the control class demonstrated only low to moderate improvement. This result supports the conclusion that integrating Wordwall with the STEM approach is effective in enhancing students' understanding of complex and abstract topics like chemical nomenclature.

These findings align with previous studies that also highlight the effectiveness of interactive and digital learning tools in science education. For example, Sahronih et al. (2020) found that interactive learning platforms significantly enhance student achievement in science. Similarly, Fitriana et al. (2024) reported that Wordwall improved student engagement and learning outcomes, even in remote learning environments. Makinde et al. (2024) also emphasized that digital tools offering real-time feedback can foster deeper and more meaningful learning experiences in chemistry.

The STEM-based learning model also contributes significantly to comprehension by promoting interdisciplinary connections and contextual application of knowledge (Wiyono et al., 2022). STEM learning encourages critical thinking and supports conceptual understanding—skills crucial to mastering chemical nomenclature, which often poses cognitive challenges for students (Ariyatun et al., 2020).

A Mann–Whitney test confirmed that the difference in post-test scores between the two groups was statistically significant ($p < 0.05$), indicating that the treatment had a meaningful impact on improving student learning outcomes.

Creativity Instrument Validation and Results

The data in Table 8 show that all four creativity aspects—fluency, flexibility, originality, and elaboration—have strong positive correlations with the overall creativity construct, with Pearson correlation values (r) above 0.60. This confirms a high level of validity for each sub-indicator. Moreover, Cronbach's Alpha coefficients exceeding 0.95 indicate excellent reliability and internal consistency in measuring student creativity, in line with research standards (Akdemir-Beveridge et al., 2025; Lou et al., 2017).

Table 8. Pearson Correlation and Reliability Test Results

Aspects of Creativity	Pearson correlation (r)	Validity interpretation	Cronbach's alpha	Reliability interpretation
Fluency	0.83	Very valid	0.9	Very reliable
Flexibility	0.63	Valid	0.9	Reliable
Originality	0.63	Valid	0.9	Reliable
Elaboration	0.78	Very valid	0.9	Very reliable

The improvement in each creativity dimension was examined using both the paired t-test and Wilcoxon signed-rank test (Cohen, 2013). The statistical results revealed significant differences between pre-test and post-test scores across all four aspects of creativity:

a) Fluency: Improved significantly (Wilcoxon: $p = 3.83 \times 10^{-5}$; t-test: $p = 0.00048$), indicating enhanced ability to express ideas fluently.
b) Flexibility: Showed substantial growth ($p = 0.00046$), suggesting better adaptability in approaching problems from multiple perspectives.

c) Originality: Increased significantly ($p = 0.00224$), reflecting higher capability in producing original ideas.
d) Elaboration: Also improved ($p = 0.0022$), though with slightly lower effect size, showing better development and refinement of ideas.

The survey results indicate clear improvements across all aspects of creativity, reinforcing the positive effect of STEM-based Wordwall integration on students' creative abilities.

Figure 2. Learning activities with the STEM approach

Figure 2 illustrates learning activities using the STEM approach, which integrates science, technology, engineering, and mathematics to promote interdisciplinary learning.

Supporting Factors Behind Learning and Creativity Improvement

Several key factors contributed to the enhancement in students' learning outcomes and creativity through the use of Wordwall and STEM-based instruction:

Interactive Learning Environment

Wordwall's gamified and interactive interface creates an engaging classroom environment that increases student motivation and active participation. This aligns with findings by Safitri et al. (2022) who noted that digital tools like Wordwall enhance intrinsic motivation and classroom engagement in STEM contexts.

Contextual and Integrated STEM Learning

The STEM approach encourages contextual learning by integrating science, technology, engineering, and mathematics in real-world problem solving. According to Yaki (2022) this integration supports deeper conceptual understanding and strengthens critical thinking—skills essential for mastering abstract content like chemical nomenclature.

Immediate Feedback and Error Correction

Wordwall provides immediate feedback, which allows students to identify and correct misconceptions promptly. Mazelin et al. (2024) emphasized that instant feedback from digital platforms increases student confidence and accelerates learning retention.

User-Friendly Digital Accessibility

The intuitive design of Wordwall lowers technological barriers, making it accessible for students with diverse digital literacy levels. This usability factor is critical in supporting consistent engagement, especially in resource-limited settings (Alisya & Titaley, 2025).

Conclusion

This study concludes that the integration of Wordwall media with a STEM-based learning approach significantly improves student learning outcomes in the topic of chemical compound nomenclature. The experimental group, which received the intervention, outperformed the control group, as demonstrated by the results of the Mann–Whitney test ($p < 0.05$). In addition to academic achievement, the application of Wordwall media also fostered the development of students' creativity, particularly in the dimensions of fluency, flexibility, and originality. Although the elaboration aspect of creativity showed an upward trend, the increase was not statistically significant, indicating that this dimension may require a different instructional strategy or longer exposure time to develop optimally. These findings support previous research emphasizing the effectiveness of STEM-based digital learning tools in promoting both cognitive and creative growth. In summary, the use of Wordwall integrated with STEM presents a promising instructional approach that enhances student engagement, understanding, and creativity in science learning contexts.

Acknowledgments

The authors extend their sincere appreciation to the Postgraduate Program of Universitas PGRI Argopuro Jember for the academic assistance and facilities provided during this research. The authors are also grateful to their supervising lecturers for their continuous guidance and constructive feedback throughout the completion of this study. Additionally, the authors acknowledge SMA Negeri Senduro for the permission granted to conduct data collection for this article.

Author Contributions

Author Contributions: Conceptualization, M.A.S.; methodology, M.A.S.; software, M.A.S.; validation, M.A.S., F.A. and R.S.D.G.; formal analysis, M.A.S.; investigation, M.A.S.; resources, M.A.S.; data curation, M.A.S.; writing—

original draft preparation, M.A.S.; writing—review and editing, M.A.S., F.A. and R.S.D.G.; visualization, M.A.S.; supervision, F.A. and R.S.D.G.; project administration, F.A. and R.S.D.G.; funding acquisition, F.A. and R.S.D.G. All authors have read and agreed to the published version of the manuscript.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

References

Aditya, M. N., & Pusposari, L. F. (2024). Pengaruh model pembelajaran game based learning dengan media wordwall terhadap hasil belajar siswa kelas viii di mtsn 1 lamongan. *Madani : Journal of Social Sciences and Social Science Education*, *2*(2), 89–99. https://doi.org/10.55210/RC9JTE05

Akdemir-Beveridge, Z. G., Zaghi, A., & Syharat, C. (2025). Understanding and Evaluating Engineering Creativity: Development and Validation of the Engineering Creativity Assessment Tool (ECAT). *Journal of Engineering Education, 114(2*), 234-245. https://doi.org/10.1002/jee.20347

Alisya, Z. W., & Titaley, A. G. (2025). Persepsi penggunaan media pembelajaran wordwall dalam pembelajaran bahasa jerman kelas xi SMAN 15 Surabaya. *Laterne*, *14*(02), 61–68. https://doi.org/10.26740/LAT.V14N02.P61-68

Ariyatun, A. (2020). Pengaruh model problem based learning terintegrasi stem terhadap kemampuan berpikir kritis siswa. *Scholar*, *2*(1), 2685–4880. https://doi.org/10.21580/jec.2020.2.1.5434

Asiyah, S. (2022). Meningkatkan hasil belajar kimia tata nama senyawa sederhana dengan model think-pair-share pada siswa kelas x sma negeri 1 lingsar improving the students' chemistry learning achievement on simple compound nomenclature through Think-Paired-Shared model at the tenth grade students of SMAN 1 Lingsar. *Reflection Journal*, *2*(1), 17–25. https://doi.org/10.36312/rj.v2i1.846

Aytaç, T., & Kula, S. (2020). The effect of student-centered approaches on students' creative thinking skills: a meta-analysis study. *International Journal of Contemporary Educational Research*, *7*(2), 62–80. https://doi.org/10.33200/ijcer.723894

Azizah, A., & Trisnawati, E. (2024). Pengaruh pembelajaran steam berbantuan media wordwall terhadap kemampuan pemecahan masalah matematika. *Jurnal Dialektika Program Studi Pendidikan Matematika, 11*(2). Retrieved from https://journal.peradaban.ac.id/index.php/jdpm at/article/view/2162

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Routledge. https://doi.org/10.4324/9780203771587/Statistical-power-analysis-behavioral-sciences-jacob-cohen

Deleña, R., & Marasigan, A. C. (2023). Understanding students' misconceptions about chemical formula writing and naming ionic compounds. *International Journal of Academic Studies in Technology and Education*, *1*(2), 156–173. https://doi.org/10.55549/IJASTE.15

English, L. D. (2016). STEM education K-12: perspectives on integration. *International Journal of STEM Education*, *3*(1), 1–8. https://doi.org/10.1186/S40594-016-0036-1/tables/2

Fauziyati, K. A. (2023). Gamification of Wordwall Maze Chase as a STEM-based learning media to improve students' creative thinking skills. *Research and Innovation in Social Science Education Journal (RISSEJ)*, *1*(1), 1–9. https://doi.org/10.30595/RISSEJ.V1I1.13

Fitriana, A., & Indriyani, D. (2024). PBL berbantuan gamifikasi wordwall untuk meningkatkan kemampuan berpikir kritis peserta didik. *Proceeding Seminar Nasional IPA*, 407–418. Retrieved from https://proceeding.unnes.ac.id/snipa/article/view/3713

Gurusinga, D. N. B., & Eddiyanto. (2025). Pengembangan dan implementasi e-modul STEM berbasis PjBL pada materi kesetimbangan kimia untuk meningkatkan hasil belajar siswa. *Jurnal Pendidikan Kimia FKIP Universitas Halu Oleo*, *10*(1), 44–58. https://doi.org/10.36709/JPKIM.V10I1.146

Gusman, T. A., Novitasari, N., & Yulina, I. K. (2023). The Effect of STEM integrated problem-based learning model on students' critical thinking skills on electrolyte and non-electrolyte solution materials. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 8911–8917. https://doi.org/10.29303/JPPIPA.V9I10.5163

Hake, R. R. (1999). *Analyzing Change/Gain Scores*. USA: Dept of Physics Indiana University.

Iswara, H., & Loka, I. N. (2021). Identifikasi kesulitan belajar kimia siswa SMA Negeri 1 Narmada selama pandemi COVID-19. *Journal of Chemistry Education and Practice,* *4*(3), 123–135. https://doi.org/10.29303/cep.v4i3.2694

Johnson, C. C., Mohr-Schroeder, M. J., Moore, T. J., & English, L. D. (2020). *Handbook of research on STEM education*. Routledge. https://doi.org/10.4324/9780429021381

Kusumaningtyas, A. W., & Yuniawatika, Y. (2024). Pengaruh Wordwall game-based learning terhadap higher order thinking skils. *Metodik Didaktik*, *20*(1), 62–73. https://doi.org/10.17509/md.v20i1.69910

Li, R., Zhu, C., Xu, B., Wang, X., & Mao, Z. (2025). *Automated creativity evaluation for large language models: A reference-based approach*. arXiv. Retrieved from https://arxiv.org/pdf/2504.15784

Lou, S.-J., Chou, Y.-C., Shih, R.-C., & Chung, C.-C.. (2017). A study of creativity in CaC2 steamship-derived STEM project-based learning. *Eurasia Journal of Mathematics, Science and Technology Education, 13(6),* 2387-2404. https://doi.org/10.12973/eurasia.2017.01231a

Makinde, S. (2024). T*he roles of emerging technology in chemistry teaching and learning for a sustainable development*. Researchgate. Retrieved from https://www.researchgate.net/profile/Semiu-Makinde/publication/386020406_The_Roles_of_Emerging_Technology_in_Chemistry_Teaching_and_Learning_for_a_Sustainable_Development/links/673fd3556dedd318c892a8ac/The-Roles-of-Emerging-Technology-in-Chemistry-Teachin

Mazelin, N., Maniam, M., Jeyaraja, S. S. B., Ng, M. M., Xiaoqi, Z., & Jingjing, Z. (2022). Using wordwall to improve students' engagement in esl classroom. *International Journal of Asian Social Science, 12*(8), 273-280. Retrieved from https://ideas.repec.org/a/asi/ijoass/v12y2022i8p273-280id4558.html

Natasha, F., Fitriani, P., Hutajulu, E. S., & Pohan, A. A. (2024). Amplifying students's understanding of the basic concept of the periodic table through wordwall in the coastal school of Riau Islands. *SHS Web of Conferences*, *205*, 06010. https://doi.org/10.1051/SHSCONF/202420506010

Nurfaijah, S., Sumarni, W., Sumarti, S., & Kurniawan, C. (2021). Pengaruh project based learning terintegrasi STEM pada pembelajaran hidrolisis garam terhadap keaktifan siswa. *CiE (Chemistry in Education)*, *10*(2), 33–41. Retrieved from http://journal.unnes.ac.id/sju/index.php/chemined

Paulus, C. S., Tengker, S. M. T., & Tuerah, J. M. (2023). Pengembangan media pembelajaran wordwall pada pelajaran kimia materi hukum dasar kimia di SMA Kr. Eben Haezar Manado. *OXYGENIUS: Journal Of Chemistry Education*, *5*(2), 92–97. https://doi.org/10.37033/ojce.v5i2.582

Prayunisa, F. (2022). Analisa kesulitan siswa kelas XI dalam pembelajaran kimia di SMAN 1 Masbagik. *Journal of Classroom Action Research*, *4*(3), 147–150. https://doi.org/10.29303/JCAR.V4I3.2095

Rahmawati, Y., Agustin, M. A., Ridwan, A., Erdawati, E., Darwis, D., & Rafiuddin, R. (2019). The development of chemistry students' 21 century skills through a STEAM project on electrolyte and non-electrolyte solutions. *Journal of Physics: Conference Series*, *1402*(5), 055049. https://doi.org/10.1088/1742-6596/1402/5/055049

Safitri, D., Awalia, S., Sekaringtyas, T., Nuraini, S., Lestari, I., Suntari, Y., Marini, A., Iskandar, R., & Sudrajat, A. (2022). Improvement of student learning motivation through Word-Wall-based digital game media. *International Journal of Interactive Mobile Technologies (IJIM), 16(6),* 109–118. https://doi.org/10.3991/ijim.v16i06.25729

Sahronih, S., Purwanto, A., & Sumantri, M. S. (2020). The effect of use interactive learning media environment-based and learning motivation on science learning outcomes. *International Journal for Educational and Vocational Studies, 2*(2), 128-137. https://doi.org/10.29103/ijevs.v2i3.2429

Siburian, P. Dela, Silalahi, Y. F., Watulingas, M. C., & Rahmadani, A. (2025). The effectiveness of the think pair square (TPSq) cooperative learning model assisted by stick media on student learning outcomes in chemical compound nomenclature. *Chimica Didactica Acta*, *13*(1), 39–44. https://doi.org/10.24815/jcd.v13i1.45852

Sinta, T., Nurfaijah, S., Sumarni, W., Sumarti, S., Kurniawan, C., & Kunci, K. (2021). Pengaruh project based learning terintegrasi stem pada pembelajaran hidrolisis garam terhadap keaktifan siswa. *Chemistry in Education, 10*(2), 33-41. Retrieved from https://journal.unnes.ac.id/sju/chemined/article/view/42710

Sugiyono, P. D. (2017). *Statistika untuk penelitian*. CV Alfabeta.

Torrance, E. P. (2012). *Torrance Tests of Creative Thinking*. PsycTESTS Dataset. https://doi.org/10.1037/T05532-000

Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of curriculum studies, 44*(3), 299-321. https://doi.org/10.1080/00220272.2021.1978660

Yaki, A. A. (2022). Fostering Critical Thinking Skills Using Integrated STEM Approach among Secondary School Biology Students. *European Journal of STEM Education*, *7*(1), 06. https://doi.org/10.20897/EJSTEME/12481

Yreck, S. (2024). The Effectiveness of STEM Education Programs on Enhancing Critical Thinking Skills Among High School Students in Malaysia. *Journal of Asian Multicultural Research for Educational Study*, *5*(2), 8–16. https://doi.org/10.47616/JAMRES.V5I2.531

Yuliardi, R., Kusumah, Y. S., Nurjanah, Juandi, D., & Suparman. (2024). Development of a STEM-based digital learning space platform to enhance students' mathematical creativity in future learning classrooms. *Eurasia Journal of Mathematics, Science and Technology Education*, *20*(12), em2545. https://doi.org/10.29333/EJMSTE/15665