E-ISSN: 2798-0472 **DOI:** 10.52562/biochephy.v6i1.1975

MO.RI Publishing

BIOCHEPHY: Journal of Science Education

BioChePhy

http://journal.moripublishing.com/index.php/biochephy

Chemistry Poster-Assisted Demonstration to Enhance Generic Science Skills in Redox Reaction Learning: A Quasi-Experimental Study of Grade XII Students

Ni Putu Erika Pebriana, Eka Junaidi*, Nora Listantia
University of Mataram, Indonesia
*Corresponding author: eka.junaidi@unram.ac.id

Abstract: This study examined the effect of the chemistry poster-assisted demonstration method on improving students' generic science skills in redox reaction material. The study was motivated by the low proportion of students reaching the Minimum Mastery Criteria (MMC) in redox material at SMA Negeri 1 Praya, alongside the limited use of instructional methods that present chemical phenomena directly to learners. A quasi-experimental design with a pretest–posttest control group format was employed, involving two Grade XII classes: one received the chemistry poster demonstration treatment, while the other received Discovery Learning combined with lecture-based instruction. The instrument consisted of validated and reliability-tested two-tier multiple-choice items. The mean score of the experimental class increased from 50.57 to 81.37 (moderate-to-high N-Gain), while the control class increased from 62.33 to 73.48 (low N-Gain). A paired-sample t-test produced a significance value (2-tailed) of 0.000 ($p < 0.05$), leading to the rejection of H_0 and acceptance of H_a. These findings indicate that the chemistry poster-assisted demonstration method has a statistically significant effect on improving students' generic science skills in redox reaction material and may be considered a viable alternative instructional strategy for abstract chemistry topics.

Keywords: demonstration method, chemistry poster, generic science skills, redox reaction

Abstrak: *Penelitian ini bertujuan untuk mengkaji pengaruh metode demonstrasi berbantuan poster kimia terhadap peningkatan keterampilan generik sains peserta didik pada materi reaksi reduksi dan oksidasi (redoks). Penelitian ini dilatarbelakangi oleh rendahnya proporsi peserta didik yang mencapai Kriteria Ketuntasan Minimal (KKM) pada materi redoks di SMA Negeri 1 Praya, serta terbatasnya penggunaan metode pembelajaran yang menyajikan fenomena kimia secara langsung kepada peserta didik. Penelitian menggunakan desain kuasi eksperimen dengan format pretest–posttest control group, yang melibatkan dua kelas XII, yaitu satu kelas diberikan perlakuan berupa metode demonstrasi berbantuan poster kimia, sedangkan kelas lainnya memperoleh pembelajaran Discovery Learning yang dipadukan dengan metode ceramah. Instrumen penelitian berupa soal pilihan ganda bertingkat (two-tier multiple-choice) yang telah dinyatakan valid dan reliabel. Rata-rata skor kelas eksperimen meningkat dari 50,57 menjadi 81,37 dengan kategori N-Gain sedang hingga tinggi, sedangkan kelas kontrol meningkat dari 62,33 menjadi 73,48 dengan kategori N-Gain rendah. Hasil uji paired-sample t-test menunjukkan nilai signifikansi (2-tailed) sebesar 0,000 ($p < 0{,}05$), sehingga H_0 ditolak dan H_a diterima. Temuan ini menunjukkan bahwa metode demonstrasi berbantuan poster kimia berpengaruh signifikan secara statistik dalam meningkatkan keterampilan generik sains peserta didik pada materi reaksi redoks dan dapat dipertimbangkan sebagai salah satu alternatif strategi pembelajaran untuk materi kimia yang bersifat abstrak.*

Kata Kunci: *metode demonstrasi, poster kimia, keterampilan generik sains, reaksi reduksi dan oksidasi*

INTRODUCTION

Chemistry is a branch of science with distinctive characteristics that differentiate it from other scientific disciplines. Most chemical concepts are abstract, hierarchical, and systematically structured, requiring students to understand relationships among concepts rather than memorise isolated facts. Chemistry also emphasises problem solving and the explanation of natural phenomena through scientific principles (Listiani et al., 2025). Effective instructional approaches are therefore essential to help students understand chemical concepts, laws, and theories, and to relate these to real-life situations.

Redox reactions are a topic that students consistently find challenging. The complexity of redox concepts arises from the need to integrate observable phenomena with invisible molecular processes. On one hand, redox reactions can be observed in everyday events such as the rusting of iron and the browning of apples after peeling or cutting (Bielsa & Miranda, 2025). On the other hand, students must grasp abstract ideas, including electron transfer, changes in oxidation number, and the balancing of redox equations. Consequently, many students develop persistent misconceptions and struggle to construct a coherent conceptual understanding (Wang et al., 2022).

These challenges suggest that conventional, teacher-centred instruction which often emphasises procedural problem solving and symbolic manipulation is insufficient for promoting deep conceptual understanding. Students instead need learning experiences that actively engage them in scientific inquiry and reasoning (Li & Liu, 2025). Recent studies show that student-centred approaches, including guided inquiry, Problem-Based Learning (PBL), project-based STEM learning, and differentiated instruction, are more effective in helping students investigate authentic problems, connect evidence with scientific concepts, and develop higher-order thinking skills (Setiawan et al., 2025).

Recent international literature further indicates that the development of generic science skills (GSS) is strengthened when instruction explicitly encourages students to observe phenomena, interpret multiple representations, formulate investigable questions, analyse evidence, communicate scientific explanations, and reflect on their own thinking (Gamby & Bauer, 2022). In redox learning specifically, instructional interventions that integrate macroscopic, sub-microscopic, and symbolic representations, visualise molecular processes, and embed inquiry within authentic contexts have been shown to improve conceptual understanding while simultaneously strengthening problem-solving ability, critical thinking, metacognitive awareness, and science process skills. Scaffolding strategies such as concept maps, guided questioning, formative feedback, advance organisers, and diagnostic treatment of misconceptions further help students connect prior knowledge with new abstract concepts and construct more coherent cognitive structures (Sabitu et al., 2022).

Conceptually, the mechanism through which such interventions promote generic science skills can be described as a sequential learning process. Contextual problems and observable phenomena first activate students' prior knowledge and motivation. Students then investigate, represent, and discuss redox processes across macroscopic, sub-microscopic, and symbolic levels. Through collaborative discussion, questioning, reflection, and formative feedback, they gradually regulate their thinking, refine scientific explanations, and reconstruct misconceptions. These experiences ultimately foster generic science skills, particularly observation, symbolic-language use, logical inference, causal reasoning, problem solving, scientific communication, and metacognitive awareness (Li & Liu, 2025).

Table 1. Daily Test Scores for Redox Reaction Material

Phase F	MMC Score	Average Score	Student Mastery (%)
XII-1	75	53.02	14.7%
XII-2	75	66.64	35.14%

Despite the growing evidence supporting student-centred learning, classroom achievement in redox chemistry remains unsatisfactory. Daily test results of Phase F Grade XII students in the 2025/2026 academic year at SMA Negeri 1 Praya showed that only 14.7% of Grade XII-1 students and 35.14% of Grade XII-2 students reached the Minimum Mastery Criteria (MMC) of 75, as presented in Table 1. These findings indicate that many students continue to struggle with mastering redox concepts and underscore the need for instructional interventions that simultaneously improve conceptual understanding and generic science skills.

Classroom observation revealed that teachers at SMA Negeri 1 Praya rarely use the demonstration method, relying instead more frequently on the Discovery Learning model; supplementary resources are occasionally limited to YouTube videos and PowerPoint presentations. Observations also indicated that students were more enthusiastic and actively engaged when teachers used methods that allowed them to witness actual transformation processes during learning.

One instructional approach that may address this problem is the demonstration method. According to McKee et al. (2007), the demonstration method conveys information by showing something directly to students. Through demonstration activities, students become more attentive to the flow of learning, engage more actively in discussion, and display greater curiosity about the chemical concepts being studied, which in turn supports the development of generic science skills such as logical reasoning, modelling, cause-and-effect thinking, and symbolic representation. One medium suited to the demonstration method is the chemistry poster, a visual-based learning medium used to display a chemical phenomenon or reaction directly during a demonstration activity (Natalia, 2023). Building on this rationale, this study aims to analyse the effect of chemistry poster-assisted demonstration on improving students' generic science skills in redox reaction material.

METHOD

This study used a quasi-experimental design, a method commonly applied to test cause-and-effect relationships between variables without full randomisation of research subjects (Anantasia, 2025). Unlike true experiments, the researcher does not have complete control over all variables and cannot apply full randomisation; this design is therefore often used in field settings where randomisation is not feasible. Specifically, this study employed a Pretest–Posttest Control Group Design and conducted at SMA Negeri 1 Praya during the even semester of the 2025/2026 academic year.

The population comprised all Grade XII students, totalling 479 students across 10 classes. The sample was selected through purposive sampling, yielding Class XII-1 as the experimental class and Class XII-2 as the control class. The independent variable was the chemistry poster-assisted demonstration method, and the dependent variable was students' generic science skills in redox reaction material. Data were collected through interviews, observation, and pretest–posttest instruments. Interviews with the chemistry teacher provided information on learning conditions and student difficulties; observation identified classroom conditions and students' need for more engaging instructional media. The test instrument consisted of two-tier multiple-choice items, in which the first tier contains the answer options and the second tier contains the reasoning supporting the chosen answer.

This instrument was developed to measure students' generic science skills, including direct observation, symbolic language, logical consistency, logical framing, and modelling. Development proceeded systematically through construct and indicator identification, preparation of an instrument blueprint, item development, and expert review of content, construction, and language. The instrument was then validated through expert judgement and empirical validity testing, followed by a reliability test to ensure consistency of measurement. These procedures were intended to ensure that the instrument met the criteria of a high-quality research instrument capable of producing accurate data on students' generic science skills.

Validity indicates the degree to which an instrument accurately reveals data on the variable under study. The instruments validated in this study included the teaching module, the student worksheets, and the pretest–posttest items. Validation was conducted by three validators: two lecturers from the Chemistry Education Programme at Universitas Mataram and one chemistry teacher from SMA Negeri 1 Praya. Expert validity was analysed using Aiken's V (Azwar, 2012), empirical validity was tested using the Product–Moment correlation (Tomoliyus & Sunardianta, 2020), and Instrument reliability or the degree of trustworthiness of an instrument as a data-collection tool was calculated using Cronbach's Alpha.

Generic science skills data were analysed descriptively by converting raw scores into the categories very good, good, fair, and poor. Improvement in generic science skills was calculated using the N-Gain formula (Sundayana, 2016), Prior to hypothesis testing, the data were tested for normality using the Chi-square test and for homogeneity using the F-test. Homogeneity was tested using the F-test (Hatami et al., 2023) and Finally, hypothesis testing was conducted using a paired-sample t-test at a 5% significance level ($\alpha = 0.05$) to determine the effect of the chemistry poster-assisted demonstration method on students' generic science skills (Arikunto, 2010).

RESULT AND DISCUSSION

Instrument Quality

Before turning to the substantive findings, it is necessary to establish that the instruments used to generate them were sound, since any subsequent claim about students' generic science skills (GSS) is only as credible as the measurement tool behind it. Three instruments were validated for this study: the teaching module, the student worksheets, and the two-tier pretest–posttest items. All three were reviewed by two chemistry education lecturers from Universitas Mataram and one practising chemistry teacher from SMA Negeri 1 Praya, and assessed using Aiken's V across content, construction, and language dimensions. Every criterion across all three instruments returned a mean Aiken's V above 0.88, ranging from 0.880 (time allocation in the teaching module) to a perfect 1.00 (learning objectives in the module; subject-matter coverage in the test items) placing all of them in the “very valid” band ($0.8 < V \leq 1.0$). This consistency across raters and across instruments suggests that the chemistry poster demonstration treatment and its accompanying assessment were grounded in content that domain experts judged appropriate, well-constructed, and linguistically accessible to Grade XII students.

Empirical validity testing of the 20 two-tier items, conducted by correlating item scores with total scores (Product–Moment correlation, r-table = 0.367 at the relevant degrees of freedom), retained 15 items as valid and flagged 5 as below threshold; these five were subsequently excluded from scoring. Cronbach's Alpha reliability for the retained item set was 0.784, which falls in the “high” category (0.61–0.80). Taken together, the validity and reliability evidence indicates that the instrument was sufficiently robust to support causal interpretation of the pretest–posttest differences reported below, rather than reflecting measurement noise or poorly worded items.

Overall Achievement Gains

Table 2. Comparison of Pretest and Posttest Scores

Statistic	Control Pretest	Control Posttest	Exp. Pretest	Exp. Posttest
Sample size	33	33	30	30
Highest score	87	100	82	100
Lowest score	27	38	20	53
Mean score	62.33	73.48	50.57	81.37

Despite starting from a lower mean score (50.57 versus 62.33 in the control class a roughly 12-point disadvantage at baseline), the experimental class finished with a substantially higher posttest mean (81.37 versus 73.48), an absolute gain of 30.80 points compared with only 11.15 points in the control class. This pattern is noteworthy in itself: the class that began further behind ended further ahead, which strengthens rather than weakens the case for the intervention's effectiveness, since a ceiling effect would have been more likely to favour the already higher-scoring control group. The lowest score in the experimental class also rose more steeply (from 20 to 53) than in the control class (from 27 to 38), suggesting that the chemistry poster demonstration benefited even the weakest-performing students in that class, not only those already close to mastery.

Normalised gain (N-Gain) scores corroborate this pattern at the level of the whole sample: the experimental class achieved a mean N-Gain of 0.572 (moderate-to-high band), compared with 0.318 in the control class (moderate-to-low band). Disaggregated by the five GSS indicators direct observation, symbolic language, logical consistency, logical framing, and modelling the experimental class outperformed the control class on four of five indicators, with direct observation showing the steepest gain (N-Gain = 0.70, high category, versus 0.16 in the control class) and modelling the only indicator on which the control class gained more (0.67 versus 0.30). Before hypothesis testing, the pretest and posttest data for both groups were confirmed to be normally distributed (χ^2-calculated below χ^2-table for both pretest and posttest) and the two groups' variances were confirmed to be homogeneous (F-calculated below F-table for both pretest and posttest), satisfying the parametric assumptions required for the subsequent paired-sample t-test. That test returned a significance value (2-tailed) of 0.000 ($p < 0.05$), leading to rejection of H_0 and acceptance of H_a: the chemistry poster-assisted demonstration method had a statistically significant effect on students' generic science skills in redox reaction material.

Why Direct Observation Improved Most

The fact that direct observation showed the largest gain is consistent with what the demonstration method is designed to do: it places a real chemical event a colour change, the formation of a precipitate, the gradual disappearance of a reactant directly in front of students rather than describing it to them. Watching iron nails oxidise next to an inhibited control, or observing the characteristic colour shift of a redox indicator, gives students a referent they can return to when later interpreting an equation or a graph. This is consistent with Pitasari and Yunaningsih (2016), who found that task-based, observation-anchored instruction produced stronger gains in generic science skills than instruction relying primarily on verbal explanation, and with the broader finding that visual, phenomenon-based demonstration supports skill development more effectively than lecture-dominated delivery (Hill et al., 2019; Razali et al., 2020). It is also consistent with McKee et al.'s (2007) original argument for demonstration laboratories: students who can see a phenomenon unfold tend to engage more attentively with the explanation that follows it, because the explanation now has something concrete to explain.

What is less obvious and worth dwelling on is why this advantage in observation appears to have propagated into the other indicators rather than remaining isolated. Symbolic-language skills improved more in the experimental class (N-Gain = 0.60 versus 0.28) plausibly because students were not asked to manipulate redox symbols and oxidation numbers in the abstract; they were asked to describe a reaction they had just watched, using those symbols as the vocabulary for doing so. This sequencing phenomenon first, symbol second mirrors the macroscopic–sub-microscopic–symbolic triad that chemistry education researchers regard as central to overcoming representational difficulties in redox chemistry (Wang et al., 2022); when students are forced to manipulate symbols before they have a referent for what those symbols represent, the symbols risk becoming an exercise in pattern-matching rather than meaning-making, which is precisely the failure mode Mulyani et al. (2016) describe in their account of how ICT-based media improved students' grasp of reaction-rate symbolism by first grounding it in observable change.

Reasoning Skills: Logical Consistency and Logical Framing

Logical-consistency gains in the experimental class (N-Gain = 0.60 versus 0.24 in the control class) appear to stem from the sequence the demonstration imposed on students' thinking: observe, identify what changed, then justify a conclusion from that change. This sequence is precisely what Prahastiwi et al. (2021) identify as the developmental pathway for logical thinking in young learners skills build more reliably when students practise drawing their own conclusions from evidence they have personally observed, rather than receiving conclusions ready-made. The demonstration format also created a natural occasion for discussion: when something unexpected happened (for instance, a slower-than-expected colour change), students had to reconcile that observation with their existing understanding, a process Susiyanti (2020) links to increased active participation and more systematic reasoning relative to lecture-only instruction. A similar logic explains the logical-framing gain (N-Gain = 0.66 versus 0.24): by comparing a substance's properties before and after a reaction side by side, students had a direct basis for contrasting physical and chemical characteristics, which is the operational definition of this indicator (Marlina, 2023; Anisak et al., 2019). It is worth noting, however, that these reasoning-related indicators improved less than direct observation itself, which suggests that observation is a necessary but not sufficient condition for reasoning gains students still required the discussion and feedback components of the demonstration session to translate what they saw into a defensible chain of reasoning, a point that aligns with Gamby and Bauer's (2022) argument that metacognitive and reasoning skills require explicit scaffolding even within otherwise activity-rich instruction.

The Modelling Anomaly

The one indicator on which the control class outperformed the experimental class modelling, where the control group's N-Gain of 0.67 exceeded the experimental group's 0.30 deserves direct attention rather than being absorbed into the overall positive narrative. Modelling, as operationalised in this study, required students to translate a sketch or illustration of a phenomenon into a formula or symbolic representation. The control class received comparatively more structured, repetitive practice in writing reaction equations and balancing oxidation numbers as part of its Discovery Learning and lecture sequence, which is precisely the kind of drilled, procedural exposure that supports this narrower symbolic-translation skill, even though it appears to do comparatively little for direct observation or reasoning (consistent with Rosidah et al., 2017, who found that modelling and symbolic-language skills respond differently to instructional format than other GSS indicators). For the experimental class, the demonstration format devoted more classroom time to observation and discussion and correspondingly less to repeated symbolic drilling, which plausibly explains its smaller though still positive gain on this specific indicator. This finding is a useful corrective to an overly simple “demonstration is better on every dimension” reading of the results: it suggests that demonstration-based instruction and procedural symbolic practice serve partly complementary rather than fully substitutable purposes, and that an optimal redox unit may need to combine both rather than replacing one with the other entirely.

Why the Control Class Underperformed

It is equally important to characterise what happened in the control class rather than treating its smaller gains only as a baseline against which the experimental class is favourably compared. Discovery Learning, in principle, is itself a student-centred model; that its outcomes here were nonetheless modest suggests that the model's benefits are sensitive to how it is implemented. Observation notes from this study indicate that Discovery Learning in the control class was paired with conventional lecture delivery and relied on PowerPoint slides and pre-recorded video rather than first-hand phenomena, which likely reduced it, in practice, to a more passive experience than the label “discovery” implies. Under these conditions, N-Gain results show that 54.55% of control-class students fell in the low category and 42.42% in the moderate category, with only 3.03% reaching the high category a distribution consistent with students encountering redox concepts mainly through secondary representations (a slide, a video clip) rather than through phenomena they generated or witnessed directly. This is consistent with broader findings that representational competence in chemistry is difficult to build through screen-mediated exposure alone, and that students exposed only to symbolic or narrated content are more prone to memorising procedures without connecting them to the underlying chemistry (Wang et al., 2022; Evina Dibyantini et al., 2020).

Theoretical and Practical Implications

Theoretically, these findings add to a growing body of chemistry-education research indicating that generic science skills are not a single undifferentiated construct that rises or falls uniformly with any "active" instructional method, but a cluster of partially independent competencies that respond differently to specific instructional features. Direct observation and reasoning-related skills appear most responsive to first-hand phenomenon exposure, whereas modelling appears more responsive to structured symbolic practice a distinction with implications for how GSS frameworks are operationalised in future redox-chemistry research (cf. Setiawan et al., 2025; Sabitu et al., 2022, on the broader role of scaffolding and advance organisers in chemistry learning).

Practically, the results suggest that chemistry teachers facing low MMC attainment in redox material the situation that originally motivated this study at SMA Negeri 1 Praya, where MMC attainment stood at only 14.7% and 35.14% across the two Grade XII classes have reason to prioritise low-cost, visually anchored demonstration over slide- or video-mediated delivery, particularly where laboratory access or equipment is limited. A chemistry poster is inexpensive, reusable, and does not require a fully equipped laboratory, which makes it a realistic option for many Indonesian public schools facing resource constraints. At the same time, the modelling anomaly indicates that demonstration should not entirely replace structured symbolic practice (equation writing, oxidation-number assignment); a blended design that opens each redox topic with poster-assisted demonstration and closes it with guided symbolic practice may capture the benefits observed in both classes here rather than only one.

Limitations

Several limitations qualify these conclusions. First, the sample was drawn from two intact classes at a single school using purposive rather than random assignment, which is a structural feature of quasi-experimental designs but nonetheless means that class-level differences unrelated to the treatment (for example, prior teacher rapport or class composition) cannot be fully ruled out as contributing factors, despite the baseline-disadvantage pattern noted above, which works against rather than for this alternative explanation. Second, the study measured outcomes immediately after the intervention; whether the experimental class's gains, particularly in direct observation and reasoning, persist over a longer interval was not assessed and remains an open question. Third, the five items dropped during empirical validity testing slightly reduce the instrument's original coverage of the intended construct map, and the modelling indicator in particular was assessed by a single item (item 5), making its result more vulnerable to item-specific noise than the other, multi-item indicators. Future replications with larger, multi-school samples, delayed post-tests, and an expanded item pool for under-represented indicators would help establish how robust and durable these effects are.

Synthesis

Taken together, the validity and reliability evidence, the overall achievement and N-Gain comparisons, and the indicator-by-indicator analysis converge on a consistent account: chemistry poster-assisted demonstration improved generic science skills primarily by giving students a concrete phenomenon to anchor their observation, language, and reasoning, and this anchoring effect was strongest precisely where the original GSS framework predicts it should be in direct observation with smaller positive spillover into symbolic language and logical reasoning, and a partial trade-off in modelling, where procedural practice rather than observation appears to be the more decisive instructional ingredient. This pattern is broadly consistent with, and extends, prior demonstration-method research in Indonesian secondary chemistry classrooms (Natalia, 2023; Marlina, 2023; Susiyanti, 2020) while adding indicator-level nuance that earlier single-outcome studies of this method did not capture.

sCONCLUSION

This study demonstrates that the chemistry poster-assisted demonstration method has a statistically significant effect on improving the generic science skills of Grade XII students at SMA Negeri 1 Praya. This is evidenced by a paired-sample t-test result of Sig. (2-tailed) = 0.000 ($p < 0.05$), indicating a significant difference in students' generic science skills before and after the treatment. The chemistry poster-assisted demonstration method can therefore be considered an effective alternative instructional approach for improving students' generic science skills, particularly for abstract topics such as redox reactions where direct observation of phenomena can bridge macroscopic, sub-microscopic, and symbolic understanding.

REFERENCES

Anantasia, G. (2025). Metodologi penelitian quasi eksperimen. Jurnal of Education, (5), 184–186.

Anisak, N., Rahayu, S., & Yahmin. (2019). Improving students' scientific reasoning and logical thinking through direct instructional activities in chemistry. *Jurnal Pendidikan Kimia Indonesia*, 3(2), 45–52.

Anwar, M., Setiabudi, A., & Martoprawiro, M. A. (2012). Desain lembaran kerja mahasiswa berbasis pembelajaran aktif-kooperatif untuk meningkatkan keterampilan generik sains mahasiswa (penerapan pada topik mekanisme reaksi). *Jurnal Chemica*, 13(1), 1–13.

Arikunto, S. (2010). *Prosedur penelitian: Suatu pendekatan praktik*. Rineka Cipta.

Azwar, S. (2012). *Reliabilitas dan validitas* (4th ed.). Pustaka Pelajar.

Bielsa, J. F., & Miranda, C. (2025). Comparative enzymatic browning transcriptome analysis of three apple cultivars unravels a conserved regulatory network related to stress responses. BMC Plant Biology.

Evina Dibyantini, R., Dwi Suyanti, R., & Silaban, R. (2020). Teacher candidate's generic science skills on organic chemistry reactions through problem-based learning model. *Humanities & Social Sciences Reviews*, 8(3), 745–754. https://doi.org/10.18510/hssr.2020.8380

Gamby, S., & Bauer, C. (2022). Beyond "study skills": A curriculum-embedded framework for metacognitive development in a college chemistry course. *International Journal of STEM Education*, 9. https://doi.org/10.1186/s40594-022-00376-6

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66(1), 64–74.

Hatami, Z., Burhanudin, Muti'ah, & Rahmawati. (2023). Pengaruh model pembelajaran problem based learning berbantuan media roda putar terhadap kemampuan berpikir kritis siswa pada materi laju reaksi di SMA Negeri 1 Labuhan Haji. *Jurnal Kimia & Pendidikan Kimia*, 5(1), 67–74.

Hill, M. A., Overton, T. L., Thompson, C. D., Kitson, R. R., & Coppo, P. (2019). Undergraduate recognition of curriculum-related skill development and the skills employers are seeking. *Chemistry Education Research and Practice*, 20(1), 68–84. https://doi.org/10.1039/C8RP00105G

Li, X., & Liu, J. (2025). TPACK-integrated redox reaction instruction: Activity model design, implementation, and evaluation. *Chemistry Teacher International*. https://doi.org/10.1515/cti-2025-0032

Listiani, H., Apriyanto, A., & Haryanti, T. (2025). *Buku ajar ilmu alamiah dasar*. PT. Sonpedia Publishing Indonesia.

Marlina, L. (2023). Pengembangan keterampilan generik sains siswa dalam pembelajaran kimia. *Jurnal Pendidikan Kimia Indonesia*, 7(2), 85–94.

McKee, E., Williamson, V. M., & Ruebush, L. E. (2007). Effects of a demonstration laboratory on student learning. *Journal of Science Education and Technology*, 16(5), 395–400.

Meltzer, D. E. (2002). The relationship between mathematics preparation and conceptual learning gains in physics: A possible "hidden variable" in diagnostic pretest scores. *American Journal of Physics*, 70(12), 1259–1268.

Mulyani, S., Liliasari, Wiji, Hana, M. N., & Nursa'adah, E. (2016). Improving students' generic skill in science through chemistry learning using ICT-based media on reaction rate and osmotic pressure material. *Jurnal Pendidikan IPA Indonesia*, 5(1), 150–156.
Natalia, D. (2023). Pengaruh metode demonstrasi terhadap peningkatan hasil belajar kognitif siswa pada penggunaan Google Docs [Doctoral dissertation].
Pitasari, R., & Yunaningsih, A. (2016). Peningkatan keterampilan generik sains siswa melalui task-based learning pada larutan buffer. *JTK (Jurnal Tadris Kimiya)*, 1(1), 1–7.
Prahastiwi, F. A., Ngazizah, N., & Khaq, M. (2021). Pengembangan lembar kerja siswa (LKS) berbasis keterampilan generik sains terintegrasi karakter pada tema 6 energi dan perubahannya di kelas III sekolah dasar. *Jurnal Pendidikan Dasar*, 2(2), 79–87.
Razali, Halim, A., Haji, A. G., & Nurfadilla, E. (2020). Effect of inquiry learning methods on generic science skills based on creativity level. *Journal of Physics: Conference Series*, 1460, 012118. https://doi.org/10.1088/1742-6596/1460/1/012118
Rosidah, T., Astuti, A. P., & Wulandari, V. D. R. A. (2017). Eksplorasi keterampilan generik sains siswa pada mata pelajaran kimia (aspek pemodelan dan simbolik). *Jurnal Pendidikan Sains*, 5(2), 130–137.
Sabitu, A., Ayodeji, I. R., & Olariwaju, L. Y. (2022). Advance organisers and secondary school students' performance in redox reactions. *Malaysian Journal of Social Sciences and Humanities*, 7(10). https://doi.org/10.47405/mjssh.v7i10.1754
Setiawan, V. R., Situmorang, M., & Silaban, R. (2025). Project-based learning with STEM to promote higher order thinking skills as a strategy to improve high school chemistry learning outcomes. *Chemistry Teacher International*, 8, 53–68. https://doi.org/10.1515/cti-2025-0025
Sugiyono. (2017). *Metode penelitian kuantitatif, kualitatif dan R&D*. Alfabeta.
Sundayana, R. (2016). *Statistik penelitian pendidikan*. Alfabeta.
Susiyanti, T. (2020). Peningkatan keterampilan berpikir tingkat tinggi melalui penerapan metode demonstrasi pada siswa kelas 2 SD Negeri Sidomulyo. *Jurnal Pendidikan Profesi Guru*, 1(3), 150–153.
Tomoliyus, T., & Sunardianta, R. (2020). Validitas dan reliabilitas instrumen tes reaktif agility tenis meja. *Jurnal Keolahragaan*, 8(2), 148–157.
Wang, L., Hodges, G., & Lee, J. (2022). Connecting macroscopic, molecular, and symbolic representations with immersive technologies in high school chemistry: The case of redox reactions. *Education Sciences*. https://doi.org/10.3390/educsci12070428