JPPIPA 11(7) (2025)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

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

Diagnosis of Difficulties in Learning Stoichiometry Based on College Students' Education Backgrounds

Raehanah[1*], Syarifatul Mubarak[1]

[1]Program Studi Tadris Kimia, Universitas Islam Negeri Mataram, Mataram, Indonesia

Received: April 24, 2025
Revised: June 17, 2015
Accepted: July 25, 2025
Published: July 31, 2025

Corresponding Author:
Raehanah
raehanah@uinmataram.ac.id

DOI: 10.29303/jppipa.v11i7.11153

Abstract: This study analyzed the learning difficulties in stoichiometry for university students at the Chemistry Department of UIN Mataram based on their upper secondary education backgrounds. This research employed a descriptive design with a quantitative approach. The sampling technique utilized was purposive sampling, targeting students who had studied stoichiometry. The research instrument was an open-ended diagnostic test form, which was validated by an expert. Data analysis techniques included calculating the percentages of question indicator completeness. The results indicated that the stoichiometric learning difficulties faced by UIN Mataram students were significant, as suggested by the percentage scores obtained in each category. Students from national senior high schools scored 41.7% (moderate), those from Islamic senior high schools scored 36.4% (high), and students from vocational high schools scored 16.7% (very high). The level of difficulties in learning stoichiometry was categorized as very high for students from national senior high schools in two areas: the application of Gay Lusac's law and Avogadro's hypothesis, and the application of the mole concept involving limiting reagents. The difficulties were also categorized as very high for students from Islamic senior high schools in three areas: the application of Gay Lusac's law and Avogadro's hypothesis, the application of the mole concept involving limiting reagents, and determining the compound formula. Furthermore, vocational senior high school students experienced very high difficulties in learning stoichiometry across seven topics, which included writing reaction equations, balancing reactions, formulating basic chemical laws, applying Gay Lusac's law and Avogadro's hypothesis, determining the relative equation (RE) and molecular formula (RM), applying the mole concept to limiting reagents, and determining the formula for hydrate compounds**.** Based on the results of this study, a differentiated learning strategy is needed to accommodate students' educational backgrounds in terms of content, process, product, and learning environment

Keywords: Difficulty In Learning; Islamic High School; Senior High School; Stoichiometry; Vocational High School.

Introduction

The difficulties experienced by students in learning chemistry cannot be separated from the characteristics of chemistry. The characteristics of chemistry influence each other between the interactions of microscopic, macroscopic, and symbolic levels, becoming challenges and difficulties for chemistry students. For example, the mole concept (Mweshi et al., 2020), atomic structure (Kelly et al., 2021), chemical bond (Lahlali et al., 2023), redox (Goes et al., 2020; Hasniyah & Muchtar, 2021), covalent bond (Danora et al., 2020), organic chemistry (Gupte et al., 2021), and others (Mubarak & Yahdi, 2020). The abstractness of chemical material makes chemistry a complex subject that is difficult to learn (Salame & Makki, 2021; Talanquer, 2022; Wu et al., 2021).

How to Cite:
Raehanah, R., & Mubarak, S. (2025). Diagnosis of Difficulties in Learning Stoichiometry Based on College Students' Education Backgrounds. *Jurnal Penelitian Pendidikan IPA*, *11*(7), 1227–1234. https://doi.org/10.29303/jppipa.v11i7.11153

Difficulty in understanding chemical concepts is partly caused by students' inability to connect the macroscopic and microscopic worlds (Talanquer, 2022). Difficulties in comprehending the material are categorized as learning difficulties. This condition is characterized by students' inability to engage in the learning process effectively due to the presence of threats, barriers, or disruptions that interfere with normal learning functioning (Nurfadhillah et al., 2022). This difficulty often arises due to a failure to master prerequisite skil (Ristiyani & Bahriah, 2016). There are at least two types of understanding that students must master to understand chemistry, known as conceptual understanding (Schwedler & Kaldewey, 2020) and algorithmic understanding (Habiddin et al., 2020).

Stoichiometry is a central topic in chemistry that focuses on the quantitative aspects of reactants and products in a chemical reaction. It is considered a fundamental chemical concept, as it is essential to master before engaging in more advanced chemical calculations (Pramilinia & Guspatni, 2024). The calculations presented in the questions can be in various forms, from the simplest to the most difficult. Questions in stoichiometry can be made from all Bloom's cognitive levels, namely C1 (knowledge), C2 (understanding), C3 (application), C4 (analysis), C5 (synthesis), and C6 (evaluation) (Uswatun & Mubarak, 2024). So, completing questions C3 to C6 requires good analytical and critical thinking skills. This material is a fairly difficult subject that causes learning difficulties and is less motivating for students (Cai, 2022). This learning difficulty will give rise to differences in understanding in students, which are called misconceptions. If the understanding that students have is different from the understanding accepted by the scientific community, then it is said that students are experiencing conceptual errors or misconceptions (Mubarak & Yahdi, 2020).

Stoichiometry misconceptions are not a new problem and have been widely expressed by researchers. Most misconceptions arise because students focus more on the algorithmic aspect and ignore the conceptual side in solving stoichiometry problems (Anugrah, 2019). The most common mistakes made when working on stoichiometry are conceptual errors and errors in concluding the answers worked out (Noorarnie et al., 2019). One of the impacts is that more than half of grade 10 and 11 students in Thailand have misconceptions about finding moles, determining molar concentration, and calculating limiting reagents (Dahsah & Coll, 2008). Generally, the symptoms are that students are still confused or do not know the definition and relationship between stoichiometric entities. (Susanty, 2022).

Understanding of stoichiometry serves as a unifying thread for the development of subsequent competencies (Fahmi & Wuryandini, 2019). Thus, chemistry students as prospective chemistry teachers must master stoichiometry competencies well. The ability to understand chemical concepts is fundamental for prospective chemistry teachers. This is stated in the professional competencies of chemistry teachers, as outlined in the appendix to Permendiknas Number 16 of 2007 point 20, outlining the competencies that must be possessed by chemistry teachers, including: 1) mastering chemical concepts; 2) understand the chemical thinking process; 3) be skilled at experimenting; and 4) reflect on performance.

Based on the results of the researcher's observations. Most of the UIN Mataram Chemistry Education students still consider the stoichiometry material to be difficult to understand. This can be seen from the results of the stoichiometry topic assignments for the last 7 years, namely 2015-2022, showing that the average class value is still low, namely 40, 35, 55, 50, 78, 65, and 58. For 2020, it has increased to 78, which is due to the online learning system that allows students to work together in completing assignments. Another cause is the diverse educational background of Chemistry Education students. Some are from general high schools, vocational high schools, and Islamic high schools, both state and private. With the students' diverse educational backgrounds, the acceptance of the material also varies. This is due to the breadth and depth of the chemistry material received in high school. The chemistry material studied by national high school students is not significantly different from that of Islamic high school students; the chemistry material of vocational high school students is quite different, namely below the national/Islamic high school chemistry material. In addition, the time allocation for chemistry in national/Islamic high schools is longer than in vocational high schools, namely 2-4 teaching hours for national/Islamic high schools, while for vocational high schools, it is adjusted to the needs of the expertise program.

Based on the factual description of stoichiometry material and the researcher's initial observations, it is necessary to conduct a diagnosis or identification of students' learning difficulties in stoichiometry. The aim is to detect the specific areas of difficulty and misconceptions students experience when studying stoichiometry. The results of this diagnosis can serve as a basis for instructors to improve their teaching practices.

Method

This type of research is descriptive research. Descriptive research describes an event that occurs at present, as it is at the time the research is carried out (Ramdhan, 2021). The subjects of this study were 73 students of UIN Mataram. Consisting of 26 students from general high schools, 43 from Islamic high schools, and 4 from vocational high schools. The sampling technique was saturated sampling and purposive sampling. It is said to be saturated sampling because all populations are research samples. It is said to be purposive sampling because the selection of samples with certain considerations, namely, all students who have studied the chapter on stoichiometry.

The instrument used in this study was a diagnostic test. The test is in the form of a description with 10 indicators. The indicators are arranged by analyzing the material so that they are sufficient to represent all the material in stoichiometry. The test is arranged based on diagnostic objectives, namely, the difficulty level is neither too low nor too difficult. Before the test instrument is used, the instrument is first tested for validity by an expert who is a chemistry lecturer. The analysis technique used is a descriptive quantitative analysis technique. How to calculate the percentage of question scores using Formula 1

$$\% \text{ score} = \frac{total\ score\ obtained}{maximum\ score}\ x\ 100\% \quad (1)$$

(Arikunto, 2021).

Next, the % score obtained is linked to Table 1 to determine the students' learning difficulties.

Table 1. Learning Difficulty Criteria

% Score	Interpretation of Learning Difficulties
0% - 20%	Very high
21% - 40%	High
41% - 60%	Medium
61% - 80%	Low
81% - 100%	Very low

(Arikunto, 2021)

The research procedure carried out can be seen in Figure 1

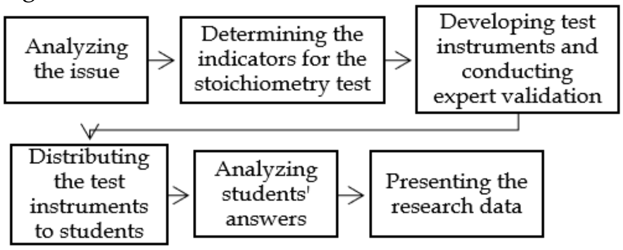

Figure 1. Research design flow

Result and Discussion

The following presents the results of the analysis of the diagnostic test answers for the stoichiometry material given to students. More details can be seen in Table 2.

Table 2. Description of Stoichiometric Diagnostic Test Values

Description	General high schools	Islamic high schools	Vocational high schools
N (total)	26	43	4
Highest score	95.5	92	31.5
Lowest score	20.5	17	13.5
Average score	50.04	43.63	20
% score	41.7 (medium)	36.4 (high)	16.7 (very high)
Standard deviation	15.6	14.5	6.7

Meanwhile, the results of the analysis of the difficulty of each indicator can be seen in Tables 3, 4, and 5. The diagram of the level of difficulty between students from general high schools, Islamic high schools, and vocational high schools can be seen in Figure 2.

Table 3. Level of Learning Difficulties among High School Students

Indicators	General high schools		Islamic High Schools		Vocational High Schools	
	% score	Criteria	% score	Criteria	% score	Criteria
Knowing the nomenclature of compounds from various types of chemical compounds	86	Very low	81	Very low	48	Medium
Writing chemical reactions based on the names of the compounds and their reaction phases	55	Medium	51	Medium	50	Medium
Balance the reaction equation correctly	56	Medium	21	High	19	Very high
Explaining the basic laws of chemistry	61	Low	60	Medium	56	Medium
Analyze and prove one of the basic laws of chemistry	28	High	35	High	20	Very high
Applying Gay Lussac and Avogadro's laws in chemical calculations	20	Very high	14	Very high	0	Very High
Applying the mole concept in chemical calculations	42	High	32	High	16	Very High
Determining the empirical formula and molecular formula of a compound	40	High	35	High	0	Very High

Indicators	General high schools		Islamic High Schools		Vocational High Schools	
	% score	Criteria	% score	Criteria	% score	Criteria
Applying the mole concept in chemical calculations involving limiting reagents	17	Very high	17	Very High	0	Very High
Determining the formula of hydrate compounds	23	High	8	Very High	0	Very High

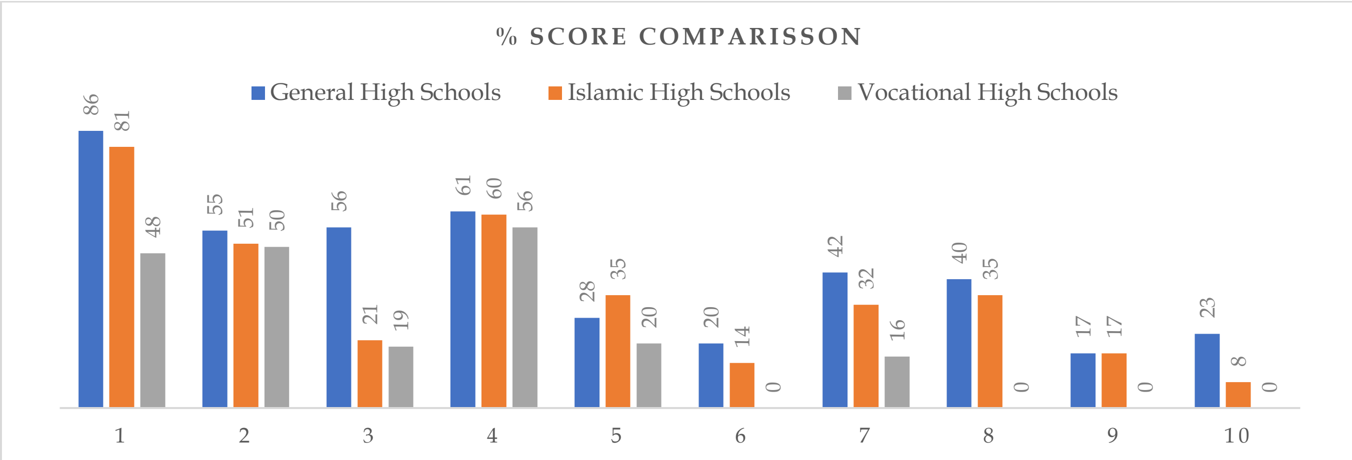

Figure 2. Diagram of Student Learning Difficulty Levels

The difficulties experienced by students in completing each indicator of the stoichiometry diagnostic test are almost the same for students from high school and Islamic high school. While students from vocational high schools are far behind. For the compound nomenclature indicator, the level of difficulty is very low, but quite high for those from vocational high school. Students can already write the names of chemical compounds well. The mistake that is often made is that some students have not been able to distinguish the nomenclature of metal-nonmetal compounds and nonmetal-nonmetal compounds. Many give names with the same rules to the two types of compounds.

The next indicator is writing a complete chemical reaction with its phase, which has a fairly high level of difficulty. Common mistakes made are writing the wrong chemical compound formula from the given compound name, and almost all do not write the reaction phase. This shows that students need to be given a deep understanding of the formation of compounds from their ions. The difficulty of these two indicators is the same as the results of Noorarnie et al.'s research, which states that there are still 33% of students who do stoichiometry problems incorrectly due to errors or not understanding the concept (Noorarnie et al., 2019).

The difficulties experienced in the material indicators of the basic laws of chemistry are proving formulas and not being able to understand the initial information to be entered into the correct formula. Some students can solve the calculation problems, but cannot apply the calculation results to the correct chemical law. In the application of Gay Lusac and Avogadro calculations, there are still many who cannot solve the problems. The level of difficulty in these basic chemical laws is categorized as quite high to very high. This shows that there are still many students who focus more on algorithmic understanding without understanding the concept first, which also states that 54% of students are still wrong in concluding the results of stoichiometric calculations (Anugrah, 2019; Noorarnie et al., 2019).

The difficulty in calculating the mole concept is that students still have difficulty choosing the right formula according to the information provided. Many use the one mole concept formula even though the information provided is different. Likewise, with determining the empirical formula and molecular formula. The use of the mole concept in calculating empirical formulas and molecular formulas is not understood by students. This is also because students do not write down information about what is known from the questions given, so students use the wrong formula, and the numbers entered are also wrong. The level of difficulty of this material is classified as high to very high. The difficulty in understanding and completing mole concept calculations is still a problem for students (Susanty, 2022).

The difficulty experienced in calculating the limiting reagent is the lack of understanding of the initial moles, reacting, and remaining. The preparation of equivalent reactions and moles written at the beginning, reacting, and students dominate student errors. So that the next calculation is wrong. The level of difficulty of this material is very high. In solving the limiting reagent, students still have difficulty determining the limiting reagent for the reaction when some compounds are added in excess (Sudirman, 2021).

The difficulty in calculating the hydrate compound formula determines that almost all students do not write the reaction of the formation of the hydrate compound. So the next step of using the concept of moles and Avogadro's law (the ratio of moles to coefficients) to solve this problem is not been done. The level of difficulty of this material is classified as high to very high. In this case, students are still confused or do not know the definition and relationship between stoichiometric entities in general (Susanty, 2022).

By looking at the average scores, students from high school have better mastery of stoichiometry material compared to students from general high schools and vocational high schools. The average score of students from high school is 50.04; from Islamic high schools, it is 43.63, and from vocational high schools, it is 20. The maximum score of this test is 120. Thus, by calculating the % difficulty of the questions in each category, students from national high school have a % difficulty of 41.7% (categorized as moderate), students from Islamic high schools have a % difficulty of 36.4% (categorized as high), and students from vocational high schools have a % difficulty of 16.7% (categorized as very high). Students from vocational high schools cannot even answer questions about the concept of moles, empirical formulas & molecular formulas, and the determination of hydrate salts. Thus, it can be said that students from vocational high schools are very far behind the others.

Differences in students' mental characteristics across Senior High School, Islamic Senior High School, and Vocational High School are influenced by the structure of their respective curricula. Students in SMA and MA focus on academic and theoretical aspects, which tends to foster analytical and critical thinking skills as well as an orientation toward higher education. In contrast, students in SMK are oriented toward technical and vocational skills, making them more accustomed to practical problem-solving and direct workforce preparation (Permendikbudristek, 2024; Ariansyah et al., 2024).

Chemistry in SMK is categorized as a vocational subject, with its instructional time adjusted based on the needs of each vocational program. It may be delivered in time blocks or alternative formats, which often results in limited instructional hours or, in some programs, the absence of chemistry instruction altogether. Meanwhile, chemistry is a compulsory subject in the natural sciences (IPA) track at SMA and MA (Permendikbudristek, 2024). As a result of these differences, SMK students receive less foundational knowledge in chemistry compared to their SMA and MA counterparts. This leads to a weaker grasp of basic chemical concepts among SMK students. These learning difficulties often stem from a lack of prerequisite skills—skills that must be mastered before advancing to more complex competencies. Prerequisite skills are essential for continued learning, as they support cognitive, social, and personal development (Nasihudin & Hariyadin, 2021).

In general, learning difficulties in stoichiometry material that are still relatively high are caused by two factors, namely internal factors and external factors. Internal factors are caused by interest, motivation, learning habits, and intellectual. While external factors are caused by the way teachers and lecturers teach (Hakim et al., 2024). Students still have many difficulties in understanding formulas and how to use them. Students generally only memorize formulas without understanding the basics. So when given questions with different types, they will definitely have difficulties. This is related to Piaget's cognitive scheme or cognitive structure. According to Piaget, the process of absorbing, processing, and storing messages that are well organized will affect children's memory. If an error occurs, it will damage mental representation and become a barrier to the formation of subsequent mental structures. The better the cognitive structure carried out by the child, the more established the child's mastery of the learning material that has been mastered.

A differentiated instructional strategy is needed to accommodate students' varying levels of prior knowledge. Differentiated instruction is an effective teaching approach that offers multiple ways for students to access and understand information. This differentiation encompasses content, process, product, and learning environment. These aspects of differentiation are closely tied to students' readiness, interests, and learning profiles (Mahfudz, 2023; Amalia et al., 2023). Differentiated instruction can serve as a strategy for teachers to meet the diverse needs of students in chemistry learning (Wahyuningsari et al., 2024), and it can enhance chemistry teachers' knowledge and confidence in improving student learning and engagement (Fahyuddin et al., 2024). When implemented properly, differentiated instruction becomes an ideal approach to learning, although it poses a challenge for teachers and lecturers to serve as creative facilitators in the classroom.

In the context of stoichiometry, differentiated instruction can be applied in the following ways: a) Content: The material should align with students' levels of understanding, including structured assignments and remedial instruction for students from vocational schools; b) Process: Teaching methods should accommodate all learners through the use of models such as Problem-Based Learning (PBL), discovery learning, blended learning, and peer tutoring (Tanjung et al., 2023; Laumarang et al., 2023); c) Product: Assessment should go beyond written tests and include formats such as portfolios and essays; d) Learning Environment: Study groups should be composed of students from diverse educational backgrounds and actively supervised by the lecturer.

Conclusion

Based on the results of the research and discussion, it can be concluded several things in this study, including: 1) the difficulty of learning stoichiometry material for UIN Mataram students is still relatively high, as evidenced by the % score obtained by each category, namely students from general high schools of 41.7% (moderate difficulty), students from Islamic High Schools of 36.4% (high difficulty), and students from vocational high schools of 16.7% (very high difficulty). 2) the level of difficulty in learning stoichiometry for students from general high schools with a very high category lies in two materials, namely: the application of Gay Lusac's law calculations and Avogadro's hypothesis with a % score of 20%, and the application of the mole concept involving limiting reagents with a % score of 16.82%. 3) The level of difficulty in learning stoichiometry for students from MA with a very high category lies in three materials, namely: application of Gay Lusac's law calculation and Avogadro's hypothesis with a score of 13.78%, application of the mole concept involving limiting reagents with a question of 16.56%, and determining the compound formula with a score of 7.5%. The level of difficulty in learning stoichiometry for students from vocational high schools with a very high category lies in seven materials, namely: a) writing reaction equations with a score of 18.75%, b) balancing reactions with a score of 20%, c) proving the basic laws of chemistry with a score of 20%, d) application of Gay Lusac's law calculation and Avogadro's hypothesis with a score of 0%, e) determining RE and RM with a score of 0%, f) application of the mole concept in limiting reagents with a score of 0%, and g) determining the formula of hydrate compounds with a score of 0%. 4) The results of this study support the implementation of differentiated instruction in higher education, across content, process, product, and learning environment, in order to meet the diverse needs of students and achieve the intended learning outcomes

Author Contributions

The first author contributes mainly to writing the original draft, the second author contributes to reviewing and editing. All research projects conducted by both authors were conducted with equal distribution of data curation, investigation, methodology, validation, visualization, and supervision.

Conflicts of Interest

Both Authors in this article declare there is no conflict of interest in the process of research, writing, and publishing this article.

References

Amalia, K., Rsyad, I., & Gunawan, A. (2023). Differentiated Learning as Learning Innovation. *Journal of Education and Teaching Learning (JETL)*, 5(2), 185-193. https://doi.org/10.51178/jetl.v5i2.1351

Anugrah, I. R. (2019). Telaah Topik Stoikiometri Sma: Miskonsepsi Dan Strategi Pembelajarannya. *Orbital: Jurnal Pendidikan Kimia*, *3*(2 SE-Articles), 94–103. https://doi.org/10.19109/ojpk.v3i2.4892

Ariansyah, K., Wismayanti, Y.-F., Safitri, R., Listatnto, V., Aswin, A., Ahad, M.-P.-Y., & Cahyarini, B.-R. (2024). Comparing labor market performance of vocational and general school graduates in Indonesia: insights from stable and crisis conditions. *Empirical Research in Vocational Education and Training*, 16(5), 1-22. https://doi.org/10.1186/s40461-024-00160-6

Arikunto, S. (2021). *Dasar-dasar evaluasi pendidikan edisi 3* (3rd ed.). Bumi aksara.

Cai, S. (2022). Harry Potter Themed Digital Escape Room for Addressing Misconceptions in Stoichiometry. *Journal of Chemical Education*, *99*(7), 2747–2753. https://doi.org/10.1021/acs.jchemed.2c00178

Dahsah, C., & Coll, R. K. (2008). Thai Grade 10 And 11 Students'understanding Of Stoichiometry And Related Concepts. *International Journal of Science and Mathematics Education*, *6*, 573–600. https://doi.org/https://doi.org/10.1007/s10763-007-9072-0

Danora, Y., Hendayana, S., & Supriatna, A. (2020). The Students' Critical Thinking Skill in Exploiting Covalent Bond Material. *Journal of Educational Sciences*, *4*(3), 478. https://doi.org/10.31258/jes.4.3.p.478-486

Fahmi, F., & Wuryandini, W. (2019). Model Community Learning Berbasis Discovery untuk Meningkatkan Softskills Stoikiometri Kimia Peserta Didik SMA. *Jurnal Inovasi Pendidikan Kimia*, *13*(1), 2268 – 2276. https://doi.org/https://doi.org/10.15294/jipk.v13i1.16759

Fahyuddin, Jahidin, Rahman, A., & Safiuddin, L.-O. (2024). Pembelajaran Berdiferensiasi Untuk Meningkatkan Pengetahuan Dan Keyakinan Guru Kimia. *Amal Ilmiah: Jurnal Pengabdian Kepada Masyarakat*, 5(2), 284-295.

https://doi.org/10.36709/amalilmiah.v5i2.206
Goes, L. F., Nogueira, K. S. C., & Fernandez, C. (2020). Limitations Of Teaching And Learning Redox: A Systematic Review. *Problems of Education in the 21st Century*, *78*(5), 698–718. https://doi.org/10.33225/pec/20.78.698
Gupte, T., Watts, F. M., Schmidt-McCormack, J. A., Zaimi, I., Gere, A. R., & Shultz, G. V. (2021). Students' meaningful learning experiences from participating in organic chemistry writing-to-learn activities. *Chemistry Education Research and Practice*, *22*(2), 396–414. https://doi.org/10.1039/D0RP00266F
Habiddin, H., Ameliana, D. N., & Su'aidy, M. (2020). Development of a Four-Tier Instrument of Acid-Base properties of salt Solution. *JCER (Journal of Chemistry Education Research)*, *4*(1), 51. https://doi.org/10.26740/jcer.v4n1.p51-57
Hakim, E., Astafani, A., & Resmawati, R. F. (2024). Systematic Review Faktor-Faktor Kesulitan Belajar Materi Kimia. *Jurnal Inovasi Pendidikan Kimia*, *18*(2), 81–88. https://doi.org/https://doi.org/10.15294/qm1ym619
Hasniyah, F., & Muchtar, Z. (2021). Pengembangan Uji Instrumen Tiga Tingkat dengan CRI untuk Mendeteksi Miskonsepsi dalam Pembelajaran Reaksi Redoks. *Jurnal Inovasi Pembelajaran Kimia*, *3*(2), 123. https://doi.org/10.24114/jipk.v3i2.26503
Kelly, R. M., Akaygun, S., Hansen, S. J. R., Villalta-Cerdas, A., & Adam, J. (2021). Examining learning of atomic level ideas about precipitation reactions with a resources framework. *Chemistry Education Research and Practice*, *22*(4), 886–904. https://doi.org/10.1039/D0RP00071J
Lahlali, A., Chafiq, N., Radid, M., Atibi, A., El Kababi, K., Srour, C., & Moundy, K. (2023). Students' Alternative Conceptions and Teachers' Views on the Implementation of Pedagogical Strategies to Improve the Teaching of Chemical Bonding Concepts. *International Journal of Engineering Pedagogy (IJEP)*, *13*(6), 90–107. https://doi.org/10.3991/ijep.v13i6.41391
Laumarang, S.-N., Odja, A.-H., & Supartin. (2023). Pengaruh Penerapan Pembelajaran Berdiferensiasi Menggunakan Model Pembelajaran Discovery Learning Terhadap Hasil Belajar Siswa pada Konsep Pemanasan Global. *Jurnal Tadris IPA Indonesia*, 3(3), 315-326. https://doi.org/10.21154/jtii.v3i3.2337
Mahfudz, M.-S. (2023). Pembelajaran Berdiferesiasi dan Penerapannya. *SENTRI: Jurnal Riset Ilmiah*, 2(2), 533-543. https://doi.org/10.55681/sentri.v2i2.534
Mubarak, S., & Yahdi. (2020). Identifying undergraduate students' misconceptions in understanding acid base materials. *Jurnal Pendidikan IPA Indonesia*. https://doi.org/10.15294/jpii.v9i2.23193
Mweshi, E., Munyati, O., & Nachiyunde, K. (2020). Teachers' Understanding of the Link between the Atomic Theory and the Mole Concept. *African Journal of Research in Mathematics, Science and Technology Education*, *24*(3), 411–422. https://doi.org/10.1080/18117295.2020.1845462
Nasihudin & Hariyadin. (2021). Pengembangan Keterampilan Dalam Pembelajaran. *Jurnal Pendidikan Indonesia,* 2(4), 733-743. Doi: https://doi.org/10.59141/japendi.v2i04.150
Noorarnie, A. M., Supardi, K. I., Sumarni, W., & Karnawan, K. (2019). Analisis kesalahan siswa dalam mengerjakan soal stoikiometri melalui langkah polya. *Jurnal Inovasi Pendidikan Kimia*, *13*(2), 2414–2424. https://doi.org/https://doi.org/10.15294/jipk.v13i2.18147
Nurfadhillah, S., Adella, A., Asfari, A. I., Anggraeny, D., Sari, N. N., & Ananda, V. (2022). Analisis Model Pelayanan Pendidikan Bagi Anak Disleksia dan Disgrafia di Sekolah Inklusi SDN Meruya Selatan 06 Pagi. *MASALIQ: Jurnal Pendidikan Dan Sains*, *2*(1), 43–52. https://doi.org/https://doi.org/10.58578/masaliq.v2i1.87
Permendikbudristek. (2024). *Kurikulum Pada Anak Usia Dini, Jenjang Pendidikan Dasar, dan Jenjang Pendidikan Menengah*. Kemendikbudristek
Pramilinia, S., & Guspatni, G. (2024). Media Pembelajaran pada Materi Stoikiometri: Sebuah Studi Literatur. *Jurnal Pendidikan Tambusai*, *8*(2 SE-Articles of Research), 20527–20539. http://jptam.org/index.php/jptam/article/view/19399
Ramdhan, M. (2021). *Metode penelitian* (1st ed.). Cipta Media Nusantara.
Ristiyani, E., & Bahriah, E. S. (2016). Analisis kesulitan belajar kimia siswa di SMAN X Kota Tangerang Selatan. *Jurnal Penelitian Dan Pembelajaran IPA*, *2*(1), 18–29. https://doi.org/https://dx.doi.org/10.30870/jppi.v2i1.431
Salame, I. I., & Makki, J. (2021). Examining the Use of PhET Simulations on Students' Attitudes and Learning in General Chemistry II. *Interdisciplinary Journal of Environmental and Science Education*, *17*(4), e2247. https://doi.org/10.21601/ijese/10966
Schwedler, S., & Kaldewey, M. (2020). Linking the submicroscopic and symbolic level in physical chemistry: how voluntary simulation-based learning activities foster first-year university students' conceptual understanding. *Chemistry Education Research and Practice*, *21*(4), 1132–1147.

https://doi.org/10.1039/C9RP00211A

Sudirman, S. (2021). Identifikasi Pemahaman Materi Stoikiometri pada Mahasiswa Baru. *Jurnal β Eta Kimia*, *1*(1), 1–6. https://ejurnal.undana.ac.id/index.php/jbk/article/view/5127

Susanty, H. (2022). Problematika Pembelajaran Kimia Peserta Didik Pada Pemahaman Konsep Dan Penyelesaian Soal Soal Hitungan. *Al Qalam: Jurnal Ilmiah Keagamaan Dan Kemasyarakatan*, *16*(6), 1929–1944. https://doi.org/http://dx.doi.org/10.35931/aq.v16i6.1278

Talanquer, V. (2022). The Complexity of Reasoning about and with Chemical Representations. *JACS Au*, *2*(12), 2658–2669. https://doi.org/10.1021/jacsau.2c00498

Tanjung, Y.-I., Wualndari, T., Lufri, Mufid, F., Andromeda, & Ramadhani, I. (2023). Model Dan Pengaruh Pembelajaran Berdiferensiasi Pada Pendidikan IPA: Tinjauan Literatur Sistematis. *Jurnal Kajian Pendidikan Dasar*, 13(1), 68-80. https://doi.org/10.24114/esjpgsd.v11i4.42751

Uswatun, & Mubarak, S. (2024). Pengembangan Instrumen Tes Diagnostik Four-Tier Untuk Mengidentifikasi Miskonsepsi Materi Konsep Mol Dan Stoikiometri. *Al Kawnu: Science and Local Wisdom Journal*, *4*(1), 34–49. https://doi.org/https://doi.org/10.18592/ak.v4i1.13838

Wahyuningsih, D., Mujiwati, Y., Hilmiyah, L., Kusumawardani, F., & Sari, I.-P. (2022). Pembelajaran Berdiferensiasi Dalam Rangka Mewujudkan Merdeka Belajar. *Jurnal Jendela Pendidikan*, 2(4), 529-535. https://doi.org/10.57008/jjp.v2i04.301

Wu, S.-H., Lai, C.-L., Hwang, G.-J., & Tsai, C.-C. (2021). Research Trends in Technology-Enhanced Chemistry Learning: A Review of Comparative Research from 2010 to 2019. *Journal of Science Education and Technology*, *30*(4), 496–510. https://doi.org/10.1007/s10956-020-09894-w