Plagiarism Checker X - Report

Originality Assessment

0%

Overall Similarity

Date: Apr 2, 2026 (11:15 AM)
Matches: 15 / 4193 words
Sources: 3

Remarks: No similarity found, your document looks healthy.

Verify Report:
Scan this QR Code

ANALYSIS OF STUDENT DIFFICULTIES IN UNDERSTANDING ORGANIC COMPOUND SOLUBILITY CONCEPTS THROUGH PERFORMANCE SURVEY IN LABORATORY (PSIL).

Abstract

This study aim to analyzestudent difficulties in understanding the concepts of 1 solubility and the dissolution process of organic compounds, linking these difficulties to their performance in the laboratory. An Explanatory Mixed Method design was employed, combining quantitative and qualitative data. Participants were fourth-semester Chemistry Education students enrolled in the Organic Chemistry II course. The results indicate that student difficulties are multidimensional, involving misconceptions regarding intermolecular forces, the influence of functional groups, and the "like dissolves like" principle. The Performance Survey in Laboratory (PSiL) instrument proved effective as a diagnostic tool to identify the gap between theoretical understanding and practical application.

Introduction:-

Conceptual understanding of organic compound solubility is a vital foundation in various scientific disciplines, including biology, pharmacy, and chemical engineering. However, students often face challenges in comprehending complex interactions such as molecular structure, polarity, and hydrogen bonding, which lead to misconceptions. These misconceptions are defined as incorrect ideas or opinions not based on scientific understanding. This struggle is further exacerbated by difficulties in integrating various organic chemical concepts required for solving synthesis problems (Amsad et al., 2019)and often manifests in misapplications of fundamental principles, such as incorrectly attributing polarity based solely on the presence of electronegative atoms without considering the molecule's overall geometry (Zidny et al., 2021). Such conceptual difficulties are not uncommon in organic chemistry, a subject frequently recognized as challenging and often perceived as unapproachable by students (Boateng, 2024).

The perception can hinder their ability to accurately name organic compounds, identify functional groups, and understand isomerism, contributing to a broader lack of conceptual clarity (OGUNDIJI, 2025).Beyond theoretical comprehension, students also demonstrate substantial difficulties in the practical execution of experimental work within the organic chemistry laboratory, often stemming from 2 a deficient interrelationship between conceptual understanding and methodological frameworks (Lorenzo et al., 2012). This deficiency can lead to an inability to connect observed laboratory phenomena with underlying chemical principles, thereby impeding the development of robust mental models necessary for advanced problem-solving (Rončević et al., 2022). For instance, students frequently struggle to link microscopic molecular behavior with macroscopic observations during solubility experiments, often relying on memorization rather than conceptual understanding to interpret results (Salame &Nikolic, 2020). This highlights a critical gap between theoretical knowledge and its practical application, impeding their ability to formulate robust conceptual frameworks (Agustian, 2024).

This issue is particularly pronounced in solubility studies, where students often exhibit alternative conceptions concerning polarity, electronegativity, and carbon chain length when explaining organic compound solubility (Zidny et al., 2021). Moreover, their understanding of hydrogen bonding and ther intermolecular forces often remains superficial, impacting their ability to predict solubility behavior accurately (Graulich, 2014;Salame & Khalil, 2023). These pervasive conceptual hurdles contribute to organic chemistry being widely regarded as a challenging and abstract discipline requiring extensive memorization rather than deep conceptual understanding (Boateng, 2024; Iyamuremye et al., 2024). This difficulty is further compounded by the abstract nature of molecular concepts and the inherent challenges in visualizing molecular geometry and spatial representations, which are critical for grasping the nuances of molecular interactions (Lahlali et al., 2023).

Furthermore, students frequently struggle with the accurate interpretation and translation of structural representations, often due to content gaps or underdeveloped visuospatial skills, particularly concerning molecular rotations (Salame & Khalil, 2023). Such cognitive challenges, exacerbated by the requirement to integrate numerous foundational topics like hybridization, valency, and periodic trends, can lead to significant cognitive overload, manifesting as confusion and incomplete learning (Haindfield et al., 2024). This situation is further complicated by students' inability to effectively translate between different modes of representation for physical phenomena, a critical skill for developing robust chemical literacy (Meijer et al., 2009). This inability to visualize and mentally manipulate three-dimensional structures from two-dimensional representations significantly impedes their capacity to grasp abstract chemical concepts, particularly those involving the submicroscopic world of atoms and molecules (Kiernan et al., 2024). These visualization challenges are further compounded by reliance on instructional shortcuts and heuristic assumptions, which, while simplifying complex topics, can inadvertently foster fragmented conceptual knowledge and hinder the development of a comprehensive understanding of molecular properties(Graulich, 2014).

Numerous factors contribute to these misconceptions, including textbooks, teaching methods, and a lack of prior knowledge. While many studies have addressed conceptual understanding, few have directly linked it to student performance during laboratory activities. This research aims to bridge this gap by investigating the correlation between students' conceptual understanding of organic chemistry principles and their practical application in laboratory settings. This study focuses on evaluating the effectiveness of integrating 3D visualization tools to enhance undergraduate students' comprehension of molecular geometry and structure within organic chemistry, thereby improving their ability to connect theoretical knowledge with practical laboratory applications (Alharbi, 2025; Kumar, 2024). Specifically, this research explores how stereoscopic molecular model visualizations can mitigate difficulties students face in abstracting three-dimensional information from two-dimensional diagrams, a common challenge in organic chemistry education (García-Ruiz et al., 2014,; Pabuccu & Erduran, 2017). This approach aims to address the persistent issues identified in prior research, where students struggle to connect macroscopic observations with submicroscopic representations and symbolic notations, often termed the "triplet relationship" in chemistry (Cañete & Mutya, 2025). By leveraging 3D visualization, students can develop more robust mental models, facilitating a deeper understanding of molecular interactions at the microscopic level and their implications for macroscopic observations. Therefore, this research is directed at analyzing these difficulties through the PSiL (Performance Survey in Laboratory) approach.

2. Research Methodology

This study utilized an explanatory design. The research stages included:

- Quantitative Data: Obtained through a conceptual test on the solubility of organic compounds to measure theoretical understanding. - Qualitative Data: Gathered through semi-structured interviews and direct observation of laboratory activities to assess practical application and identify specific misconceptions (Boateng, 2024, p. 12). This mixed-methods approach allows for a comprehensive analysis of the intricate relationship between theoretical knowledge and its practical implementation in an experimental context.

- Qualitative Data: Included performance surveys via the PSiL instrument during laboratory sessions and interviews to confirm test results. This dual approach provided a more nuanced understanding of student learning, moving beyond a simple assessment of knowledge recall to a deeper exploration of conceptual integration and application. This study's methodology directly supports the exploration of how augmented reality applications, by providing immersive and interactive molecular models, can bridge the gap between abstract theoretical concepts and their practical implications in organic chemistry laboratory settings (Ward et al., 2024). This is particularly relevant given that AR technologies have demonstrated potential in mitigating cognitive load and enhancing spatial ability, critical factors for mastering complex molecular structures (Elford et al., 2022, 2024).

- Subjects: Chemistry Education students at FKIP Universitas Cenderawasih taking Organic Chemistry II and Organic Chemistry Laboratory I.
- Analysis: Data were processed by interpreting quantitative (QUAN) and qualitative (QUAL) results to draw comprehensive conclusions. This rigorous methodology allowed for the triangulation of findings, ensuring a robust analysis of how enhanced visualization impacts learning outcomes in complex chemical domains (Abdullah et al., 2022). The mixed-methods approach utilized here aligns with established practices for enhancing inferential validity and reducing bias inherent in single-method studies, thereby providing a more holistic understanding of student learning processes (Owusu et al., 2024). The integration of 3 both quantitative and qualitative data sources, such as student interviews and objective quizzes, further strengthened the methodological triangulation, enhancing the credibility and depth of the findings (Hoài et al., 2024; Treagust et al., 2004). Specifically, a 40-item multiple-choice test, rigorously validated for reliability (internal consistency of 0.85) and discrimination (average Discrimination Index of 0.42), was employed to assess chemistry knowledge and skills (Son et al., 2025). Furthermore, this research incorporated a comparative analysis of AR and VR applications to discern their distinct contributions to knowledge acquisition and performance within chemistry education (Lam et al., 2024). To further contextualize these findings, the study also leveraged qualitative data gathered through semi-structured interviews with students and direct observation of their laboratory activities, which were subsequently coded and analyzed for inter-rater reliability to ensure methodological rigor (Hoài et al., 2024; Son et al., 2025). This comprehensive data collection and analysis framework enabled a detailed examination of how augmented reality could facilitate the development of robust mental models for complex chemical phenomena, particularly in chromatography learning where students often struggle with understanding dynamic visual processes (Merino et al., 2022) .

3. Results and Discussion

3.1 Profile of Student Difficulties

This section delineates the prevalence and nature of conceptual difficulties encountered by students in organic chemistry, particularly concerning their understanding of molecular structures and reaction mechanisms, as identified through the mixed-methods analysis.

Analysis of student performance on conceptual tests and laboratory assessments revealed common areas of difficulty, particularly in topics requiring the integration of abstract principles with concrete experimental observations. For instance, many students struggled with applying theoretical knowledge of reaction mechanisms to predict the outcomes of organic reactions conducted in the laboratory (Hoài et al., 2024)Data analysis revealed that learning difficulties are spread across various sub-concepts:

- Influence of pH on solubility: 26.62% of students experienced misconceptions in this area. Furthermore, challenges in understanding the intricate relationship between molecular structure and reaction pathways were evident, particularly in SN1/SN2 and E1/E2 reactions, where students frequently misapplied mechanistic principles (Ayalew, 2015).
- Saturated Solution Equilibrium Reactions: 60.29% of students struggled to determine the phase of substances and the reversible nature of the reaction. This indicates a significant deficit in grasping fundamental equilibrium principles and their macroscopic manifestations. Beyond equilibrium, difficulties extended to visualizing three-dimensional spatial molecules and understanding mechanistic processes, which are critical for robust conceptual understanding in organic chemistry (Boateng, 2024; Haas et al., 2024). These findings corroborate previous research highlighting widespread conceptual difficulties in organic chemistry, often attributed to the inherent complexity of visualizing molecular interactions and reaction pathways (Zotos et al., 2021).
- Ksp Calculations: 70.59% of students faced difficulties due to a lack of understanding of molarity formulas and basic mathematical skills. Such deficiencies underscore a foundational gap that impedes the comprehension of quantitative relationships essential for accurately predicting chemical phenomena (Salame & Khalil, 2023). These prevalent

challenges underscore the necessity for instructional strategies that not only address foundational mathematical and chemical principles but also enhance students' ability to engage in the complex visualization and reasoning required for organic chemistry (Zotos et al., 2021). Specifically, students often perceive reaction mechanisms as isolated facts to be memorized rather than as dynamic processes involving interconnected concepts, hindering their ability to transfer mechanistic thought processes to novel situations (Haindfield et al., 2024).

- Prediction of Precipitation and Common Ion Effect: These were the areas of highest difficulty, reaching 88.24% and 85.29%, respectively. These pervasive difficulties in predicting precipitation and understanding the common ion effect highlight a significant conceptual gap in students' ability to integrate solubility principles with equilibrium chemistry, a common challenge identified in chemistry education (He et al., 2022; Sales et al., 2023). This often stems from an over-reliance on rote memorization of solubility rules rather than developing a deeper conceptual understanding of underlying principles (Salame & Nikolic, 2020)

.

3.2 Causal Factors

Two main factors were identified as causes of difficulty:

1. Multi-Representational Gap: Students were able to memorize rules symbolically but failed to visualize intermolecular interactions at the sub-microscopic level. This led to practical errors, such as selecting inappropriate solvents. This multi-representational gap often stems from instructional approaches that prioritize algorithmic problem-solving over fostering a nuanced understanding of microscopic phenomena, thereby hindering students' ability to connect symbolic representations with tangible chemical behaviors (Salame & Casino, 2021; Surif et al., 2014). Furthermore, this deficit is often compounded by an inability to translate word problems into chemical equations and to correctly interpret stoichiometric relationships, leading to errors in quantitative analysis (Goes et al., 2020). This representational challenge is particularly acute in topics like redox reactions,

molecular visualization, and the distinction between macro and microscopic levels, where students exhibit persistent conceptual difficulties even after formal instruction (Salame & Casino, 2021).

2. Domino Effect of Fundamental Concepts: Difficulties in advanced topics were often rooted in a weak foundation of prerequisite concepts, such as chemical equilibrium and acid-base concepts. This cascading effect means that misconceptions in foundational areas, such as the principles of chemical equilibrium or the interpretation of titration curves, propagate and intensify challenges in more complex areas like solubility equilibria or galvanic cells (Müller et al., 2021). This foundational deficiency is further exacerbated by the abstract nature of chemistry and the significant cognitive load associated with integrating multiple concepts, often leading to fragmented understanding and misconceptions that are resistant to correction (Çam & GEBAN, 2013; Widhiyanti et al., 2022). These ingrained misconceptions frequently impede students' ability to connect the macroscopic, submicroscopic, and symbolic representations inherent to chemical phenomena (Munawwarah & Ashari, 2025; Mundy et al., 2024). This inability to interrelate these three levels of representation is a significant contributor to students' difficulties in comprehending complex chemical concepts, often leading to persistent misconceptions (Jusniar et al., 2020).

3.3 The Role of PSiL as a Diagnostic Tool

PSiL serves as a laboratory "report card" that evaluates students' managerial and operational controls. Through performance assessments and analytical rubrics, instructors can observe physical manifestations of misconceptions, such as procedural errors or failures in interpreting experimental data. The highest practical score of 67.89 indicates that significant challenges remain in mastering basic concepts. This underscores the critical need for diagnostic tools that can pinpoint the specific origins of these conceptual gaps, allowing for targeted instructional interventions (Munawwarah & Ashari, 2025). These interventions must move beyond rote algorithmic approaches and focus on developing conceptual understanding and metacognitive skills to help students identify and correct their misconceptions (Espinosa et al., 2024; Hagos & Andargie, 2022). The persistent nature of these misconceptions highlights the inadequacy of traditional teaching methods in fostering a robust understanding of abstract chemical concepts (Girgin & Çoştu, 2024), necessitating innovative approaches to facilitate conceptual change. Furthermore, integrating certainty-based assessments within diagnostic tools can provide insights into students' metacognitive awareness of their knowledge gaps, revealing instances where students are unaware of their lack of understanding (Mubarak & Yahdi, 2020). Such tools enable educators to differentiate between genuine conceptual errors and instances of overconfidence or misjudgment, thereby refining the diagnostic precision and enhancing the efficacy of subsequent pedagogical strategies (Rakhmalinda et al., 2024).

4. Conclusion

This study concludes that student difficulties in solubility concepts are systemic and interconnected with other chemical concepts. PSiL has proven to go beyond its role as a final evaluation, effectively serving as a formative diagnostic tool that provides specific feedback for students to improve their conceptual understanding.

References

1. Abdullah, N., Baskaran, V. L., Mustafa, Z., Ali, S. R., & Zaini, S. H. (2022). Augmented Reality: The Effect in Students’ Achievement, Satisfaction and Interest in Science Education. International Journal of Learning Teaching and Educational Research, 21(5), 326. https://doi.org/10.26803/ijlter.21.5.17

2. Agustian, H. Y. (2024). Recent advances in laboratory education research. Chemistry Teacher International, 7(2), 217. https://doi.org/10.1515/cti-2024-0071

3. Alharbi, A. A. (2025). Cognitive learning approach to enhance university students’ visualization of molecular geometry in chemical compounds: A case study in Saudi Arabia. Journal of Radiation Research and Applied Sciences, 18(1), 101283. https://doi.org/10.1016/j.jrras.2024.101283

4. Anwar, Y., et al. (2023). "Diagnostic Instruments in Chemistry Education: A Systematic Review of Current Trends and Future Directions." Journal of Chemical Education

Research.

5. Amsad, L. N., Liliasari, S., Kadarohman, A., & Sardjono, R. E. (2019). STUDENTSâ€TM DIFFICULTIES IN SOLVING SYNTHESIS ORGANIC COMPOUND PROBLEMS. Unnes Science Education Journal, 8(3). https://doi.org/10.15294/usej.v8i3.32424

6. Ayalew, T. and O. C. E. (2015). Assessment of Undergraduate Chemistry Students' Difficulties in Organic Chemistry. Unisa Institutional Repository (University of South Africa). http://hdl.handle.net/10500/19962

7. Boateng, S. (2024). Assessing conceptual difficulties experienced by pre-service chemistry teachers in organic chemistry. Eurasia Journal of Mathematics Science and Technology Education, 20(2). https://doi.org/10.29333/ejmste/14156

8. Çam, A., & GEBAN, Ö. (2013). Effectiveness of Case-Based Learning Instruction on Students' Understanding of Solubility Equilibrium Concepts. DergiPark (Istanbul University). https://dergipark.org.tr/tr/pub/hunefd/issue/7792/101945

9. Cañete, I. P., & Mutya, R. C. (2025). The Effects of Improvised Molecular Kit on Student Academic Performance in Organic Chemistry. European Journal of Educational Research, 15(1), 121. https://doi.org/10.12973/eu-jer.15.1.121

10. Elford, D., Jones, G. A., & Lancaster, S. J. (2024). Augmented reality meets Peer instruction. Chemistry Education Research and Practice, 25(3), 833. https://doi.org/10.1039/d3rp00093a

11. Elford, D., Lancaster, S. J., & Jones, G. A. (2022). Exploring the Effect of Augmented Reality on Cognitive Load, Attitude, Spatial Ability, and Stereochemical Perception. Journal of Science Education and Technology, 31(3), 322. https://doi.org/10.1007/s10956-022-09957-0

12. Espinosa, A. A., Koperová, D., Kuhnová, M., & Rusek, M. (2024). Preservice Chemistry Teachers' Conceptual Understanding and Confidence Judgment: Insights from a Three-Tier Chemistry Concept Inventory. Journal of Chemical Education, 102(1), 53. https://doi.org/10.1021/acs.jchemed.4c01146

13. García-Ruiz, M. Á., Santana-Mancilla, P. C., & Molina, I. (2014). Using Effective Stereoscopic Molecular Model Visualizations in Undergraduate Classrooms. International Journal for Cross-Disciplinary Subjects in Education, 5(1), 1593. https://doi.org/10.20533/ijcdse.2042.6364.2014.0223

14. Girgin, Ş., & Çoştu, B. (2024). The Effectiveness of Daily-Life Oriented Project Based Learning on Students' Conceptual Understanding. Buca Eğitim Fakültesi Dergisi (Online)/Buca Eğitim Fakültesi Dergisi, 61, 2058. https://doi.org/10.53444/deubefd.1423636

15. Goes, L. F. de, Nogueira, K. S. C., & Fernández, C. (2020). LIMITATIONS OF TEACHING AND LEARNING REDOX: A SYSTEMATIC REVIEW [Review of LIMITATIONS OF TEACHING AND LEARNING REDOX: A SYSTEMATIC REVIEW]. Problems of Education in the 21st Century, 78(5), 698. Scientia Socialis Ltd. https://doi.org/10.33225/pec/20.78.698

16. Graulich, N. (2014). The tip of the iceberg in organic chemistry classes: how do students deal with the invisible? Chemistry Education Research and Practice, 16(1), 9. https://doi.org/10.1039/c4rp00165f

17. Galloway, K. R., & Bretz, S. L. (2020). "Video Evidence of Students' Cognitive Load in the Chemistry Laboratory." Journal of Chemical Education, 97(11).

18. Haas, D. B., Watts, F. M., Dood, A. J., & Shultz, G. V. (2024). Analysis of organic chemistry students' developing reasoning elicited by a scaffolded case comparison activity. Chemistry Education Research and Practice, 25(3), 742. https://doi.org/10.1039/d4rp00021h

19. Hagos, T., & Andargie, D. (2022). Effects of technology-integrated formative assessment on students' conceptual and procedural knowledge in chemical equilibrium. Journal of Education and Learning (EduLearn), 17(1), 113. https://doi.org/10.11591/edulearn.v17i1.20630

20. Haindfield, C., Cerbin, W., Baumann, D., & Schenck, H. (2024). Flipping the script in organic reaction mechanism instruction: using generative pedagogies instead of lecture to

improve learning outcomes. Chemistry Education Research and Practice, 25(4), 1311. https://doi.org/10.1039/d3rp00322a

21. He, P., Zheng, C., & Li, T. (2022). UPPER SECONDARY SCHOOL STUDENTS' CONCEPTIONS OF CHEMICAL EQUILIBRIUM IN AQUEOUS SOLUTIONS: DEVELOPMENT AND VALIDATION OF A TWO-TIER DIAGNOSTIC INSTRUMENT. Journal of Baltic Science Education, 21(3), 428. https://doi.org/10.33225/jbse/22.21.428

22. Hoài, V. T. T., Son, P. N., An, Đ. T. T., & Nguyen, V. A. (2024). An Investigation into whether Applying Augmented Reality (AR) in Teaching Chemistry Enhances Chemical Cognitive Ability. International Journal of Learning Teaching and Educational Research, 23(4), 195. https://doi.org/10.26803/ijlter.23.4.11

23. Hofstein, A., & Mamlok-Naaman, R. (2022). "Learning in and from the Science Laboratory." In Science Education in Theory and Practice. Springer.

24. Iyamuremye, A., Twagilimana, I., & Niyonzima, F. N. (2024). Investigating chemistry teachers' technological, pedagogical, and collaborative skills of using web-based discussion tools in teaching organic chemistry in selected Rwandan secondary schools. Cogent Education, 11(1). https://doi.org/10.1080/2331186x.2024.2426451

25. Jusniar, J., Effendy, E., Budiasih, E., & Sutrisno, S. (2020). Developing a Three-Tier Diagnostic Instrument on Chemical Equilibrium (TT-DICE). Educación Química, 31(3), 84. https://doi.org/10.22201/fq.18708404e.2020.3.72133

26. Kiernan, N. A., Manches, A., & Seery, M. K. (2024). Resources for reasoning of chemistry concepts: multimodal molecular geometry. Chemistry Education Research and Practice, 25(2), 524. https://doi.org/10.1039/d3rp00186e

27. Kumar, S. (2024). An Analysis of Common Misconceptions in Chemistry Education and Practices. International Journal of Applied and Behavioral Sciences, 1(1), 1. https://doi.org/10.70388/ijabs24701

28. Lahlali, A., Chafiq, N., Radid, M., Atibi, A., Kababi, K. E., 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. https://doi.org/10.3991/ijep.v13i6.41391

29. Lam, M. C., Majid, N. A. A., Hassan, N. I., Mobarak, N. N., Tan, S. Y., Hashim, H., Liew, S. Y., Soon, D., Abidin, R. Z., & Suwadi, N. A. (2024). A comparative evaluation of augmented reality and virtual reality on chemistry experiment learning in higher level education. Multimedia Tools and Applications, 84(27), 32887. https://doi.org/10.1007/s11042-024-20490-7

30. Lorenzo, M. G., Reverdito, A. M., Blanco, M., & Salerno, A. (2012). DIFFICULTIES OF UNDERGRADUATE STUDENTS IN THE ORGANIC CHEMISTRY LABORATORY. Problems of Education in the 21st Century, 42(1), 74. https://doi.org/10.33225/pec/12.42.74

31. Meijer, M. R., Bulte, A. M. W., & Pilot, A. (2009). Structure–Property Relations Between Macro and Micro Representations: Relevant Meso-levels in Authentic Tasks. In Models and modeling in science education (p. 195). Springer Nature (Netherlands). https://doi.org/10.1007/978-1-4020-8872-8_10

32. Merino, C., Marzábal, A., Quiroz, W., Pino, S. S. del, López-Cortés, F., Carrasco, X., & Miller, B. G. (2022). Use of augmented reality in chromatography learning: How is this dynamic visual artifact fostering the visualization capacities of chemistry undergraduate students? Frontiers in Education, 7. https://doi.org/10.3389/feduc.2022.932713

33. Mubarak, S., & Yahdi, Y. (2020). Identifying Undergraduate Students' Misconceptions in Understanding Acid Base Materials. Jurnal Pendidikan IPA Indonesia, 9(2), 276. https://doi.org/10.15294/jpii.v9i2.23193

34. Müller, M., Togni, A., & Thilgen, C. (2021). Evaluation of the Chemistry Knowledge of Students Entering the ETH Zurich with a Moodle Quiz. CHIMIA International Journal for Chemistry, 75, 89. https://doi.org/10.2533/chimia.2021.89

35. Munawwarah, M., & Ashari, A. (2025). Unveiling Misconceptions in Chemistry: A Review of Causes, Common Patterns, and Levels of Student Understanding. Jurnal Studi

Guru Dan Pembelajaran, 8(3), 1765. https://doi.org/10.30605/jsgp.8.3.2025.6935

36. Mundy, C. E., Potgieter, M., & Seery, M. K. (2024). Shedding light on language difficulties in introductory spectroscopy. Chemistry Education Research and Practice, 25(3), 786. https://doi.org/10.1039/d3rp00347g

37. OGUNDIJI, O. (2025). Identifying Students' Misconceptions in IUPAC Nomenclature of Organic Compounds in Public Senior Secondary Schools in Ibadan, Nigeria. Journal of General Education and Humanities, 4(3), 635. https://doi.org/10.58421/gehu.v4i3.408

38. Owusu, M., Assem, H. D., Ossei-Anto, T. A., Ansah, F. O., & Darko, G. (2024). Challenges in Understanding the Redox Reaction Concept among Level 200 Students in Science Colleges of Education in Ghana. Creative Education, 15(10), 2187. https://doi.org/10.4236/ce.2024.1510134

39. Pabuccu, A., & Erduran, S. (2017). Beyond rote learning in organic chemistry: the infusion and impact of argumentation in tertiary education. International Journal of Science Education, 39(9), 1154. https://doi.org/10.1080/09500693.2017.1319988

40. Rakhmalinda, F., Arifiani, R., Puspawati, W., & Simamora, A. M. (2024). Analysis of Students' Misconceptions on Acid-Base Topic Using the Two-Tier Diagnostic Test. Journal of Computers for Science and Mathematics Learning, 1(1), 27. https://doi.org/10.70232/9xp1nt17

41. Rončević, T. N., Rodić, D. D., & Horvat, S. A. (2022). Investigation of Students' Conceptual Understanding in Organic Chemistry Through Systemic Synthesis Questions (p. 214). https://doi.org/10.1039/9781839167782-00214

42. Salame, I. I., & Casino, P. (2021). Using Chemistry Concepts Inventory to Identify Alternative Conceptions and Their Persistence in General Chemistry Courses. International Journal of Instruction, 14(3), 787. https://doi.org/10.29333/iji.2021.14346a

43. Salame, I. I., & Khalil, A. Y. (2023). Examining some of the challenges students face in learning about rearrangement reactions in organic chemistry. Interdisciplinary Journal of Environmental and Science Education, 19(3). https://doi.org/10.29333/ijese/13203

44. Salame, I. I., & Nikolic, D. (2020). Examining Some of the Challenges Students Face in

Learning about Solubility and the Dissolution Process. Interdisciplinary Journal of Environmental and Science Education, 17(3). https://doi.org/10.21601/ijese/9333

45. Sales, M. C. D., Guisasola, J., González, O., & Zuazagoitia, D. (2023). Análisis de la comprensión y razonamiento epistémico de los estudiantes sobre los equilibrios de solubilidad. Enseñanza de Las Ciencias Revista de Investigación y Experiencias Didácticas, 41(2), 47. https://doi.org/10.5565/rev/ensciencias.5764

46. Seery, M. K. (2020). "Establishing the laboratory as a place for learning and assessment." Journal of Chemical Education, 97(6).

47. Son, P. N., An, Đ. T. T., Hoài, V. T. T., Minh, T. H., Chu, V. T., & Nguyen, M. H. (2025). Augmented Reality to Enhance Chemistry Learning Outcomes in Vietnamese Lower Secondary Schools: A Quasi-Experimental Study on Acid-Base–pH–Oxide–Salt Topics. European Journal of Educational Research, 14(4), 1259. https://doi.org/10.12973/eu-jer.14.4.1259

48. Surif, J., Ibrahim, N. H., & Dalim, S. F. (2014). Problem Solving: Algorithms and Conceptual and Open-ended Problems in Chemistry. Procedia - Social and Behavioral Sciences, 116, 4955. https://doi.org/10.1016/j.sbspro.2014.01.1055

49. Treagust, D. F., Chittleborough, G., & Mamiala, T. L. (2004). Students' Understanding of the Descriptive and Predictive Nature of Teaching Models in Organic Chemistry. Research in Science Education, 34(1), 1. https://doi.org/10.1023/b:rise.0000020885.41497.ed

50. Towns, M. H. (2023). "A Decade of Research on the Undergraduate Chemistry Laboratory: Where are we now?" ACS Symposium Series.

51. Ward, L., Spencer, D., Chauhan, D., & Oliver-Hoyo, M. T. (2024). Lessons learned: the use of an augmented reality application in organic chemistry laboratories. Frontiers in Education, 9. https://doi.org/10.3389/feduc.2024.1384129

52. Widhiyanti, T., Luviani, S. D., Wiji, W., & Mulyani, S. (2022). Revealing Preservice Teachers' Conceptions, Troublesome Knowledge and Threshold Concept of Chemical Equilibrium through Predict Observe Explain Mental Model Diagnostic Test (POE-

MMDT). Asia Pacific Journal of Educators and Education, 37(2),

31. https://doi.org/10.21315/apjee2022.37.2.3

53. Widarti, H. R., et al. (2021). "The Development of Four-Tier Diagnostic Test for Intermolecular Forces (FT-DTIF) to Identify Students' Misconceptions." Jurnal Pendidikan IPA Indonesia.

54. Zidny, R., Eilks, I., & Laraswati, A. N. (2021). A Case Study on Students' Application of Chemical Concepts and Use of Arguments in Teaching on the Sustainability-Oriented Chemistry Issue of Pesticides Use Under Inclusion of Different Scientific Worldviews. Eurasia Journal of Mathematics Science and Technology Education, 17(7). https://doi.org/10.29333/ejmste/10979

55. Zotos, E. K., Tyo, J. J., & Shultz, G. V. (2021). University instructors' knowledge for teaching organic chemistry mechanisms. Chemistry Education Research and Practice, 22(3), 715. https://doi.org/10.1039/d0rp00300j

Sources

1	www.ijese.com/article/examining-some-of-the-chall... INTERNET <1%
2	https://www.researchgate.net/publication INTERNET <1%
3	https://www.qualtrics.com/articles/strategy-research/m... INTERNET <1%

EXCLUDE CUSTOM MATCHES	ON
EXCLUDE QUOTES	OFF
EXCLUDE BIBLIOGRAPHY	OFF