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2
3 **ANALYSIS OF STUDENT DIFFICULTIES IN UNDERSTANDING ORGANIC COMPOUND**
4 **SOLUBILITY CONCEPTS THROUGH PERFORMANCE SURVEY IN LABORATORY (PSIL).**
5

6 ***Abstract***
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8 This study aim to analyzestudent difficulties in understanding the concepts of solubility and the dissolution process
9 of organic compounds, linking these difficulties to their performance in the laboratory. An Explanatory Mixed
10 Method design was employed, combining quantitative and qualitative data. Participants were fourth-semester
11 Chemistry Education students enrolled in the Organic Chemistry II course. The results indicate that student
12 difficulties are multidimensional, involving misconceptions regarding intermolecular forces, the influence of
13 functional groups, and the "like dissolves like" principle. The Performance Survey in Laboratory (PSiL) instrument
14 proved effective as a diagnostic tool to identify the gap between theoretical understanding and practical application.
15

16 **Introduction:-**

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

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

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

46 Furthermore, students frequently struggle with the accurate interpretation and translation of structural
47 representations, often due to content gaps or underdeveloped visuospatial skills, particularly concerning molecular
48 rotations (Salame & Khalil, 2023). Such cognitive challenges, exacerbated by the requirement to integrate numerous
49 foundational topics like hybridization, valency, and periodic trends, can lead to significant cognitive overload,

50 manifesting as confusion and incomplete learning (Haindfield et al., 2024). This situation is further complicated by
51 students' inability to effectively translate between different modes of representation for physical phenomena, a
52 critical skill for developing robust chemical literacy (Meijer et al., 2009). This inability to visualize and mentally
53 manipulate three-dimensional structures from two-dimensional representations significantly impedes their capacity
54 to grasp abstract chemical concepts, particularly those involving the submicroscopic world of atoms and molecules
55 (Kiernan et al., 2024). These visualization challenges are further compounded by reliance on instructional shortcuts
56 and heuristic assumptions, which, while simplifying complex topics, can inadvertently foster fragmented conceptual
57 knowledge and hinder the development of a comprehensive understanding of molecular properties (Graulich, 2014).

58 Numerous factors contribute to these misconceptions, including textbooks, teaching methods, and a lack of prior
59 knowledge. While many studies have addressed conceptual understanding, few have directly linked it to student
60 performance during laboratory activities. This research aims to bridge this gap by investigating the correlation
61 between students' conceptual understanding of organic chemistry principles and their practical application in
62 laboratory settings. This study focuses on evaluating the effectiveness of integrating 3D visualization tools to
63 enhance undergraduate students' comprehension of molecular geometry and structure within organic chemistry,
64 thereby improving their ability to connect theoretical knowledge with practical laboratory applications (Alharbi,
65 2025; Kumar, 2024). Specifically, this research explores how stereoscopic molecular model visualizations can
66 mitigate difficulties students face in abstracting three-dimensional information from two-dimensional diagrams, a
67 common challenge in organic chemistry education (García-Ruiz et al., 2014.; Pabuccu & Erduran, 2017). This
68 approach aims to address the persistent issues identified in prior research, where students struggle to connect
69 macroscopic observations with submicroscopic representations and symbolic notations, often termed the "triplet
70 relationship" in chemistry (Cañete & Mutya, 2025). By leveraging 3D visualization, students can develop more
71 robust mental models, facilitating a deeper understanding of molecular interactions at the microscopic level and their
72 implications for macroscopic observations. Therefore, this research is directed at analyzing these difficulties through
73 the PSiL (Performance Survey in Laboratory) approach.

74 2. Research Methodology

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

- 76 • **Quantitative Data:** Obtained through a conceptual test on the solubility of organic compounds to measure
77 theoretical understanding. - **Qualitative Data:** Gathered through semi-structured interviews and direct
78 observation of laboratory activities to assess practical application and identify specific misconceptions
79 (Boateng, 2024, p. 12). This mixed-methods approach allows for a comprehensive analysis of the intricate
80 relationship between theoretical knowledge and its practical implementation in an experimental context.
- 81 • **Qualitative Data:** Included performance surveys via the PSiL instrument during laboratory sessions and
82 interviews to confirm test results. This dual approach provided a more nuanced understanding of student
83 learning, moving beyond a simple assessment of knowledge recall to a deeper exploration of conceptual
84 integration and application. This study's methodology directly supports the exploration of how augmented
85 reality applications, by providing immersive and interactive molecular models, can bridge the gap between
86 abstract theoretical concepts and their practical implications in organic chemistry laboratory settings (Ward
87 et al., 2024). This is particularly relevant given that AR technologies have demonstrated potential in
88 mitigating cognitive load and enhancing spatial ability, critical factors for mastering complex molecular
89 structures (Elford et al., 2022, 2024).
- 90 • **Subjects:** Chemistry Education students at FKIP Universitas Cenderawasih taking Organic Chemistry II
91 and Organic Chemistry Laboratory I.
- 92 • **Analysis:** Data were processed by interpreting quantitative (QUAN) and qualitative (QUAL) results to
93 draw comprehensive conclusions. This rigorous methodology allowed for the triangulation of findings,
94 ensuring a robust analysis of how enhanced visualization impacts learning outcomes in complex chemical
95 domains (Abdullah et al., 2022). The mixed-methods approach utilized here aligns with established
96 practices for enhancing inferential validity and reducing bias inherent in single-method studies, thereby

97 providing a more holistic understanding of student learning processes (Owusu et al., 2024). The integration
98 of both quantitative and qualitative data sources, such as student interviews and objective quizzes, further
99 strengthened the methodological triangulation, enhancing the credibility and depth of the findings (Hoài et
100 al., 2024; Treagust et al., 2004). Specifically, a 40-item multiple-choice test, rigorously validated for
101 reliability (internal consistency of 0.85) and discrimination (average Discrimination Index of 0.42), was
102 employed to assess chemistry knowledge and skills (Son et al., 2025). Furthermore, this research
103 incorporated a comparative analysis of AR and VR applications to discern their distinct contributions to
104 knowledge acquisition and performance within chemistry education (Lam et al., 2024). To further
105 contextualize these findings, the study also leveraged qualitative data gathered through semi-structured
106 interviews with students and direct observation of their laboratory activities, which were subsequently
107 coded and analyzed for inter-rater reliability to ensure methodological rigor (Hoài et al., 2024; Son et al.,
108 2025). This comprehensive data collection and analysis framework enabled a detailed examination of how
109 augmented reality could facilitate the development of robust mental models for complex chemical
110 phenomena, particularly in chromatography learning where students often struggle with understanding
111 dynamic visual processes (Merino et al., 2022)

113 3. Results and Discussion

114 3.1 Profile of Student Difficulties This section delineates the prevalence and nature of conceptual difficulties 115 encountered by students in organic chemistry, particularly concerning their understanding of molecular 116 structures and reaction mechanisms, as identified through the mixed-methods analysis.

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

- 122 • **Influence of pH on solubility:** 26.62% of students experienced misconceptions in this area. Furthermore,
123 challenges in understanding the intricate relationship between molecular structure and reaction pathways
124 were evident, particularly in SN1/SN2 and E1/E2 reactions, where students frequently misapplied
125 mechanistic principles (Ayalew, 2015).
- 126 • **Saturated Solution Equilibrium Reactions:** 60.29% of students struggled to determine the phase of
127 substances and the reversible nature of the reaction. This indicates a significant deficit in grasping
128 fundamental equilibrium principles and their macroscopic manifestations. Beyond equilibrium, difficulties
129 extended to visualizing three-dimensional spatial molecules and understanding mechanistic processes,
130 which are critical for robust conceptual understanding in organic chemistry (Boateng, 2024; Haas et al.,
131 2024). These findings corroborate previous research highlighting widespread conceptual difficulties in
132 organic chemistry, often attributed to the inherent complexity of visualizing molecular interactions and
133 reaction pathways (Zotos et al., 2021).
- 134 • **Ksp Calculations:** 70.59% of students faced difficulties due to a lack of understanding of molarity
135 formulas and basic mathematical skills. Such deficiencies underscore a foundational gap that impedes the
136 comprehension of quantitative relationships essential for accurately predicting chemical phenomena
137 (Salame & Khalil, 2023). These prevalent challenges underscore the necessity for instructional strategies
138 that not only address foundational mathematical and chemical principles but also enhance students' ability
139 to engage in the complex visualization and reasoning required for organic chemistry (Zotos et al., 2021).
140 Specifically, students often perceive reaction mechanisms as isolated facts to be memorized rather than as
141 dynamic processes involving interconnected concepts, hindering their ability to transfer mechanistic
142 thought processes to novel situations (Haindfield et al., 2024).

- 143 • **Prediction of Precipitation and Common Ion Effect:** These were the areas of highest difficulty, reaching
144 88.24% and 85.29%, respectively. These pervasive difficulties in predicting precipitation and
145 understanding the common ion effect highlight a significant conceptual gap in students' ability to integrate
146 solubility principles with equilibrium chemistry, a common challenge identified in chemistry education (He
147 et al., 2022; Sales et al., 2023). This often stems from an over-reliance on rote memorization of solubility
148 rules rather than developing a deeper conceptual understanding of underlying principles (Salame &
149 Nikolic, 2020)

151 3.2 Causal Factors

152 Two main factors were identified as causes of difficulty:

- 153 1. **Multi-Representational Gap:** Students were able to memorize rules symbolically but failed to visualize
154 intermolecular interactions at the sub-microscopic level. This led to practical errors, such as selecting
155 inappropriate solvents. This multi-representational gap often stems from instructional approaches that
156 prioritize algorithmic problem-solving over fostering a nuanced understanding of microscopic phenomena,
157 thereby hindering students' ability to connect symbolic representations with tangible chemical behaviors
158 (Salame & Casino, 2021; Surif et al., 2014). Furthermore, this deficit is often compounded by an inability
159 to translate word problems into chemical equations and to correctly interpret stoichiometric relationships,
160 leading to errors in quantitative analysis (Goes et al., 2020). This representational challenge is particularly
161 acute in topics like redox reactions, molecular visualization, and the distinction between macro and
162 microscopic levels, where students exhibit persistent conceptual difficulties even after formal instruction
163 (Salame & Casino, 2021).
- 164 2. **Domino Effect of Fundamental Concepts:** Difficulties in advanced topics were often rooted in a weak
165 foundation of prerequisite concepts, such as chemical equilibrium and acid-base concepts. This cascading
166 effect means that misconceptions in foundational areas, such as the principles of chemical equilibrium or
167 the interpretation of titration curves, propagate and intensify challenges in more complex areas like
168 solubility equilibria or galvanic cells (Müller et al., 2021). This foundational deficiency is further
169 exacerbated by the abstract nature of chemistry and the significant cognitive load associated with
170 integrating multiple concepts, often leading to fragmented understanding and misconceptions that are
171 resistant to correction (Çam & GEBAN, 2013; Widhiyanti et al., 2022). These ingrained misconceptions
172 frequently impede students' ability to connect the macroscopic, submicroscopic, and symbolic
173 representations inherent to chemical phenomena (Munawwarah & Ashari, 2025; Mundy et al., 2024). This
174 inability to interrelate these three levels of representation is a significant contributor to students' difficulties
175 in comprehending complex chemical concepts, often leading to persistent misconceptions (Jusniar et al.,
176 2020).

177 3.3 The Role of PSiL as a Diagnostic Tool

178 PSiL serves as a laboratory "report card" that evaluates students' managerial and operational controls. Through
179 performance assessments and analytical rubrics, instructors can observe physical manifestations of misconceptions,
180 such as procedural errors or failures in interpreting experimental data. The highest practical score of 67.89 indicates
181 that significant challenges remain in mastering basic concepts. This underscores the critical need for diagnostic tools
182 that can pinpoint the specific origins of these conceptual gaps, allowing for targeted instructional interventions
183 (Munawwarah & Ashari, 2025). These interventions must move beyond rote algorithmic approaches and focus on
184 developing conceptual understanding and metacognitive skills to help students identify and correct their
185 misconceptions (Espinosa et al., 2024; Hagos & Andargie, 2022). The persistent nature of these misconceptions
186 highlights the inadequacy of traditional teaching methods in fostering a robust understanding of abstract chemical
187 concepts (Girgin & Çoştu, 2024), necessitating innovative approaches to facilitate conceptual change.

188 Furthermore, integrating certainty-based assessments within diagnostic tools can provide insights into students'
189 metacognitive awareness of their knowledge gaps, revealing instances where students are unaware of their lack of

190 understanding (Mubarak & Yahdi, 2020). Such tools enable educators to differentiate between genuine conceptual
191 errors and instances of overconfidence or misjudgment, thereby refining the diagnostic precision and enhancing the
192 efficacy of subsequent pedagogical strategies (Rakhmalinda et al., 2024).

193 4. Conclusion

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

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